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Studies on Hookworm, Ascaris and Trichuris In Panama

Embodying the Results of the Researches of an Expedition to the Republic of Panama, May to September, 1926

By

W. W. CORT, N. R. STOLL, W. C. SWEET,
W. A. RILEY and LOUIS SCHAPIRO

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This report is dedicated to

BAILEY K. ASHFORD

AND

CHARLES WARDELL STILES

whose work in establishing the endemicity and importance of hookworm disease in the American tropics and the Southern United States laid the foundations for a control program in the Western Hemisphere.

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FOREWORD.

In the summer of 1926 an expedition was sent out from the Department of Helminthology of the School of Hygiene and Public Health of the Johns Hopkins University to make studies on the hookworm problem in Central America. The expedition was financed by a grant from the International Health Division of the Rockefeller Foundation. Cordial invitations had been received from the Governments of Panama and Nicaragua to make the investigations in these countries. The expedition was under the general direction of Dr. W. W. Cort, Professor of Helminthology in the Johns Hopkins University. In Panama the work was carried out in close cooperation with the Department of Uncinariasis, with the help of Dr. Louis Schapiro, the field director of the International Health Division of the Rockefeller Foundation. In Nicaragua the cooperation was obtained through the help of Dr. D. M. Molloy, of the Rockefeller Foundation, who placed the facilities of the Department of Uncinariasis at the disposal of the visiting investigators. Both Dr. Schapiro and Dr. Molloy took active parts in the researches. The other members of the expedition were Dr. M. C. Hall, Chief of the Zoological Division of the Bureau of Animal Industry of the U. S. Department of Agriculture, Dr. W. A. Riley, Professor of Zoology at the University of Minnesota, Dr. W. C. Sweet of the International Health Division of the Rockefeller Foundation, Dr. D. L. Augustine, Assistant Professor of Helminthology, Harvard University Medical School and Drs. N. R. Stoll * and H. W. Brown * of the Department of Helminthology of the Johns Hopkins University.

After spending a few weeks in Panama, Drs. Hall and Augustine proceeded to Nicaragua where they made a series of studies on anthelminthics. The rest of the group worked in Panama with headquarters at Penonome, Cocle Province. This report includes only the results of the studies in Panama on hookworm, ascaris and trichuris. To give a better idea of the whole work of this expedition a list is given below of the papers already published and those which are planned from those of the researches not included in this report.

* Dr. Stoll is now an Associate Member of the Rockefeller Institute in the Department of Animal Pathology at Princeton, N. J. and Dr. Brown is Research Associate in Pharmacology in Vanderbilt University Medical School.

In addition Dr. Hall took home with him an extensive collection of the parasites of domesticated and wild animals which is being worked up by the staff of the Zoological Division of the Bureau of Animal Industry, U. S. Department of Agriculture.

It is a pleasure to express our appreciation of the cooperation of the International Health Division of the Rockefeller Foundation which made this expedition possible. We wish also to express our gratitude to the officials of Panama and Nicaragua for their interest and help, and to all those connected with the Departments of Uncinariasis of these two countries who aided in various phases of our program. We also want to take this opportunity to thank Miss Blanche Wheeler, Mr. O. R. McCoy and Dr. J. A. Scott for help in preparation of the manuscript for publication. W. W. Cort.

List of publications from the results of the Central American Expedition not included in this report.

Hall, M. C.

1927. The parasite problems of the live stock industry in the United States and in Central America. Jour. Amer. Vet. Med. Asso., *70*, 935–946.

1928. Parasitological and other observations in Central America. Cornell Vet., *18*, 1–18.

Hall, M. C., and Augustine, D. L.

Some investigations of anthelminthics by the egg and worm count method. (MS.) To be published in 1928 or early in 1929.

Schapiro, Louis, and Stoll, N. R.

1927. Preliminary note on the anthelminthic value of tetrachlorethylene based on egg counts before and after one treatment. Amer. Jour. Trop. Med., *7*, 193–198.

Brown, H. W.

1927. Human ascaris as a household infection. Jour. Parasit., *13*, 206–212.

1927. Studies on the rate of development and viability of the eggs of *Ascaris lumbricoides* and *Trichuris trichiura* under field conditions. Jour. Parasitol., *14*, 1–15.

1927. A study of the regularity of egg-production of *Ascaris lumbricoides*, *Necator americanus* and *Trichuris trichiura*. Jour. Parasitol., *14*, 110–119.

Brown, H. W., and Cort, W. W.

1927. The egg production of *Ascaris lumbricoides*. Jour. Parasitol., *14*, 88–89.

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I. THE SITUATION IN PANAMA WITH RELATION TO THE HOOKWORM PROBLEM.

By

W. W. CORT and LOUIS SCHAPIRO.

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A. Introduction.

The intensity of the hookworm infestation in any region is primarily determined by its general climatic and physiographic features and secondarily by the habits of the people living in it. The primary factors for which the relationship is most clearly understood are temperature, rainfall, type of soil and drainage. Among the secondary

factors which are most clearly significant are occupational habits, which bring the people in contact with the soil, and personal habits such as the wearing of shoes or those related to defecation. The climatic factors may vary somewhat from year to year but cannot be modified or controlled. On the other hand those habits of the people which are particularly favorable to the dissemination of the hookworm may be modified, either unconsciously or with deliberate intent, so that the level of the infestation may be radically changed. To understand the hookworm situation in any area, therefore, it is necessary to consider all the factors both primary and secondary which combine to produce the particular level of infestation which is found to exist.

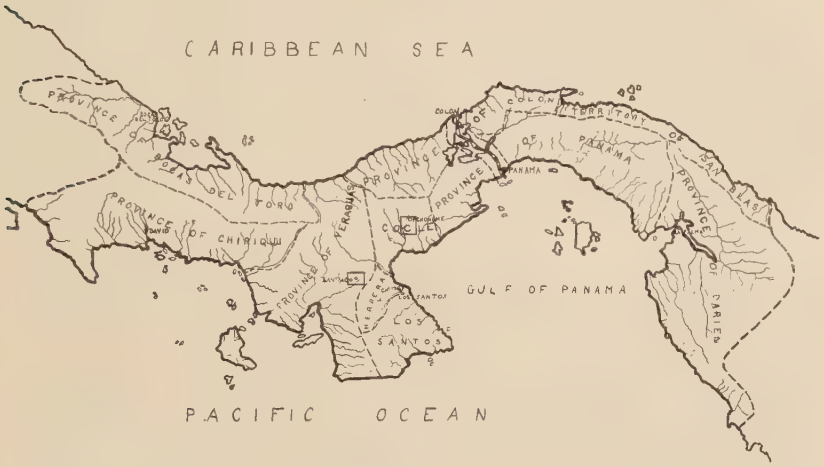
In presenting the results of our Panama investigations carried on in the summer of 1926, it is necessary not only to tell something of the whole country and its people but also to consider particularly the areas in which our studies were made. One of the most important objects of our work was to try to determine to what extent the control measures which had been employed in Panama since 1914 have reduced the amount of hookworm. In this introductory section, we will, therefore, following a brief description of the Republic of Panama and its people, give the history of the general course of the control measures which have been carried out against hookworm disease. We will also summarize the information available on the incidence of hookworm in Panama which has accumulated in the course of the control campaign. For the areas which we studied in particular in the summer of 1926 we will give more detailed descriptions so that the situation at the time we undertook our investigations can be judged.

B. General discussion of the Republic of Panama.

The Republic of Panama forms the link connecting North and South America. Its position, which is shown in the map (Map 1) is, contrary to the general impression, almost due east and west and not north and south. This country has an area of approximately 34,000 square miles, about that of South Carolina, of which approximately 13,500 square miles are inhabited. It is quite mountainous with several peaks of more than 10,000 feet in height. The coastal plains are cut by 480 rivers which flow more or less directly from the mountains to the sea. Of these rivers 197 are perennial and the remainder are dry during the summer season.

A series of prairies occupies extensive areas in the Provinces of Chiriqui, Veraguas, Los Santos, Cocle and Panama. These plains extend from the coast, 10 to 35 miles, to the low foothills. They

appear to the newcomer similar to the prairies of the southwestern United States. Of the 13,500 square miles which are inhabited almost 8,000 are this prairie land. It is especially surprising to find most of the people in the rural districts of Panama living in an open country with comparatively few trees.



Map I. The Republic of Panama, showing the provinces.

There are two seasons in Panama, the dry, from January to April and the rainy, from April to December. An exception to this is the Province of Bocas del Toro where the dry season lasts eight months, from March to October and the rainy season only four months. The heaviest rains occur during the months of October and November. On the Atlantic coast the average annual rainfall is 140 inches, on the Pacific, 60 inches and in the interior, 95 inches. Certain restricted zones have a rainfall as high as 200 inches. The average temperature during the dry season on the Atlantic and Pacific coasts is about 80° F. with a daily range of about 10° F. It is cooler in the foothills and mountains with a mean of 65° F. but these regions are very sparsely settled except in the Province of Chiriqui. During the rainy season the temperature is somewhat higher with a greater humidity. Along the Atlantic littoral the heat is excessive during the dry season, although tempered to some extent by ocean breezes. It is thus apparent that most of the inhabited regions of Panama have a warm moist period for about eight months of the year that is favorable for the development of the soil stages of the hookworm. Therefore, where the habits of the people are favorable, heavy hookworm infestation would be expected.

According to the census of 1920, the estimated mid-year population of the Republic of Panama for 1926 was 325,000, excluding the cities of Panama and Colon, the Canal Zone, and the San Blas Indians. The average density of population is about 12 per square mile. This provincial population of 325,000 is exposed to hookworm infestation. The racial distribution reported by the Bureau of Statistics is as follows: white, 11 per cent.; negro, 12 per cent.; Indian, 11 per cent.; yellow, 0.5 per cent.; and mestizo or mixtures 65.5 per cent. About 20 per cent. of these people live in towns or villages of 500 to 5,000 population and 80 per cent. live in the rural areas. Approximately 90 per cent. of the provincial population lives to the west of the Panama Canal and 80 per cent. along the Pacific slope. The Province of Darien and the Territory east of the Canal are sparsely settled. The inhabitated areas of the Pacific littoral are limited to the wide coastal plains and the low foothills. It can be seen, however, that even in these areas where the bulk of the rural population lives its density is quite sparse.

Panama is essentially an agricultural country where banana cultivation produces the single large item for export, and sugar cane and animal husbandry for local consumption. The extensive plains of rich pastures in the rainy season, and the low foothills in the dry season are utilized for grazing purposes. The cattle industry is in the hands of the owners of large tracts of land. The "cow men" and their families live in small clusters of mud or thatch houses, along the roads or trails. Each household cultivates a small plot of land with bananas, plantain, corn, rice, yucca, yame and beans for family use and the surplus production is sold to the neighboring village. Oranges and avocates are consumed in large quantities when in season and for the poor the mango is the staple food from June to September. Hogs and fowls are raised in haphazard fashion and are in most instances the only source of funds to provide the necessities of the family. As yet insufficient food stuffs are produced for local consumption and rice and beans are imported in large quantities. The cultivation of bananas for export is limited to comparatively small areas in the Province of Bocas del Toro and the Intendencia of San Blas. The laborers in these zones are chiefly negroes.

For administrative purposes the republic is divided into provinces, which are subdivided into municipal districts. The provinces are governed by governors appointed by the President, and the municipal districts by Alcaldes (Mayors) appointed by the governor. A Municipal Council is elected every two years by popular election. The

Municipal Districts are of varying size with a village of 500 or more, as the district capital, and an outlying area with isolated houses or small groups of houses along natural horse or cart trails. The Municipalities are autonomous in the control of local sanitation. Sanitary ordinances are given out by the Alcaldes but the sanitary decrees of the national government are also required to be enforced. The revenues of the municipal districts are very small, a situation which precludes any attempt on their part to undertake formal health measures. The National Department of Uncinariasis initiated its labors during 1914 and was the only health agency until January 12, 1925 when the National Assembly enacted an organic law authorizing the Government to organize a National Department of Hygiene and Public Health and to issue the necessary decrees regulating its activities.

C. Course of hookworm campaign in Panama from July 15, 1914 to December 31, 1926.

1. *Personnel and organization.*

The hookworm campaign in the Republic of Panama started July 15, 1914 and was placed on a definite legal basis with the formation of the Department of Uncinariasis by the Government of Panama by a decree promulgated September 2, 1915.* The information on the methods used during the campaign is taken from the reports of the different directors which have been issued throughout the course of the campaign and which were loaned us from the library of the Rockefeller Foundation. The first series of these reports through 1919 were mimeographed and given a limited distribution, but since that time the reports have been filed and only the parts of them which were summarized in the Annual Reports of the International Health Board have been published.

From the beginning of the work of the Department of Uncinariasis

* The work was at first under the Direction of Dr. L. W. Hackett, representing the International Health Board of the Rockefeller Foundation. On January 15, 1916, Dr. W. T. Burres relieved Dr. Hackett as the representative of this organization and continued as medical director until March 1919, with a short break from July 1 to November 13, 1918, when during his absence in the United States his place was taken by Dr. J. L. Rice. Dr. F. A. Miller, who relieved Dr. Burres in March 1919, continued in charge of the work until May 1, 1920, when Dr. Fred C. Caldwell became medical director. In February 1922, Dr. Caldwell was forced to return to the United States by a severe illness, leaving the work in charge of Senor Remulo Roux, the field director. Finally in 1923, Dr. Louis Schapiro was placed in charge of the work, in which position he still continues.

a central office with a laboratory and dispensary has been maintained in Panama City. Field units for examination and treatment of the people have been established which have worked at different points in the interior and later a system of sanitary inspectors gradually developed. As early as 1915 there were three field units each under the immediate direction of a technical assistant and each with two microscopists. The total staff that year consisted of the medical director, an assistant medical director, one clerical assistant, three technical assistants, and six microscopists. With minor fluctuations this personnel and organization remained about the same through 1920. After this time the emphasis on the sanitary phases of the work caused the staff to be increased by the addition of sanitary inspectors. The total personnel of the Department of Uncinariasis for 1926 was as follows: one medical director, one field director, three technical assistants, eight to ten sanitary inspectors, seven to nine microscopists, three to six porters, and three special government sanitary inspectors.

2. *General course of the campaign.*

The campaign in Panama has been conducted in general by the dispensary method and the sanitary work has followed rather slowly the examination and treatment phases. This course of procedure has differed markedly from that followed in certain other regions in Tropical America. The chief factors which have determined this course for the campaign have been the sparseness and scattered character of the population and the unusual difficulties of travel in the interior especially in the rainy season. At its inception the work was carried on by travelling dispensaries where people were examined and treated. At first there was no attempt to establish cure by re-examination and retreatment, but as early as the end of 1915, reexaminations were made a part of the routine after the second treatment, wherever revisits to the villages could be made without too much expense. Educational work in the form of personal talks, school lectures, public lectures, and the distribution of posters, pamphlets, and leaflets was carried on actively from the very first of the campaign. In the early years of the work patients were allowed to take the medicine home with them. Since this method proved wasteful more and more personal supervision was given to treatments until beginning with 1917 it became the rule that all treatments were administered personally by members of the staff. It seems probable that the real effectiveness of the treatment work must, therefore be dated from

1917. In the last quarter of 1920 it was decided to concentrate all the working units in one province, instead of having them widely separated as previously. Soon after this the method of procedure in the campaign was changed to mass treatment, without the preliminary or follow-up fecal examinations.

The ground covered by the early work is indicated by the fact that at the end of 1921, 49 of the 61 districts into which the 8 provinces of Panama are divided had been covered by the treatment campaign. In these districts 99,381 individuals out of the 125,979 examined had been found positive for hookworm (78.9 per cent.) and 90,486 of these had been given one or more treatments. These districts embraced the readily accessible villages of the provinces of Bocas del Toro, Cocle, Herrera, Chiriqui and parts of the provinces of Veraguas, Los Santos, Panama and Colon. In all these districts with the exception of those in Veraguas and a few in Chiriqui the work of examination and treatment had been completed before active sanitary measures were begun. It was only toward the end of 1919 that backed by a Presidential decree requiring the construction of sanitary latrines for every house in the interior of the Republic, the Department of Uncinariasis had any chance to stress presanitation. The program was developed at this time to carry out a sanitary campaign in all the districts previously covered to be followed by a second treatment campaign. This campaign which started in Veraguas was carried to Cocle in January 1922, where all the units were concentrated. In this province from February to May all the members of the staff were engaged in the sanitary work of latrine construction and for the remaining months of the year they were used in examinations and treatments, the province being covered by the end of 1922. About this time a regular sanitary inspector service for the latrines was established in Veraguas and Cocle. This service has been increasingly stressed and extended as new areas were covered with the sanitary campaign. During 1921 and 1922 the mass treatment method began to be practised. This consisted of the administration of the treatments without preliminary examination or reexamination to all those in whom treatment was not contraindicated. This method has been continued as the routine procedure, being almost universally carried out from July 1923, after which time the total number of examinations made was very greatly reduced.

By the end of 1926 the sanitary campaign work followed by treatment, which was instituted in Veraguas in 1921 had been practically completed in the provinces of Veraguas, Herrera, Los Santos and

Cocle, and work was under way in Chiriqui and Panama. The work in the areas which had been covered had settled down for the most part to a routine sanitary campaign which attempted by the inspection service to conserve the latrines which were built, to extend sanitation to the unprovided houses and to administer treatment to the school children. In order to give a better understanding of the course of the campaign which has been just outlined further details will be given of the methods of examination and treatment and of the methods used in the development of the sanitary phases.

3. *Examination and treatment.*

Because of the heavy infestation in Panama the principal method of examination used throughout the campaign has been the direct smear. Usually two by three inch slides have been used and three to five slides have been examined before a specimen was declared negative. Beginning with 1923 examination of negatives by the Willis floatation method was established for the provincial laboratories. In the central laboratory the present method is to combine the Willis and the Stoll egg counting technic. In the last year or two the dilution egg counting method has been introduced into certain rural areas where it is being used to obtain a quantitative measure of the results of the control methods and for the comparison of different population groups. Recent work suggests that this method can be very helpful in checking the procedure in the routine campaign.

An examination of the reports of the Panama campaign shows an interesting development of the methods of treatment during the course of the work. At first thymol was the only drug used but by the end of 1915 oil of chenopodium was already in use in one laboratory. For both drugs a preliminary purge of magnesium sulphate was given on the afternoon or evening before treatment. The drugs were given in divided doses and a second purge was given two hours after the second dose. As mentioned above, it was not until 1917 that all the treatments were supervised personally by members of the staff. By the end of 1918 oil of chenopodium was gaining ground. The dosage for thymol was 3 grains for each year with a maximum of 60 grains (3.888 grams), given as outlined above. As a routine procedure two treatments were given 7 days apart with the first reexamination after the second treatment. With oil of chenopodium the adult dose was 30 minims (given only to robust adults) and two treatments ten days apart were given before reexamination. In estimating the dosage by age the physical development and hemoglobin reading were chiefly

considered. By 1919 oil of chenopodium was used in the majority of cases with a larger maximum dosage running up to 3 mils or 3.5 mils in exceptional cases.

In 1920 the dosage of chenopodium, which had by this time become the drug of choice, was reduced following the recommendation of the Uncinariasis Commission of the Orient to an adult dose of $1\frac{1}{2}$ mils (24 minims) since it was considered that any possible advantages of the larger dose were outweighed by its danger. No change was reported in the technic of administering treatments in 1922 or 1923 except that in 1923 only three treatments were given to each patient which were administered at an interval of 10 days without further re-examination. In the same year a trial was made of carbon tetrachloride in the district of Los Santos with excellent results. Due to the danger of abnormal livers produced by alcoholism this drug was not given to males over 18 years of age. No further records of experimentation with carbon tetrachloride are given in the later reports and oil of chenopodium has remained almost the only drug used in Panama.

During the course of the hookworm campaign in Panama up to December 31, 1926 a total of 397,333 treatments were given to 175,785 patients covering most of the republic especially the most populated regions. Table 1 gives the records of treatments given each year

TABLE 1.

Treatments administered in Panama each year, from 1914 to 1925.

Year.	First treatment.	Total treatments.
1914	2,562	3,141
1915	14,918	26,793
1916	23,747	50,491
1917	17,900	41,705
1918	9,642	21,830
1919	10,951	22,900
1920	8,353	13,697
1921	7,861	20,536
1922	13,732	34,324
1923	15,418	37,300
1924	13,487	33,110
1925	20,585	49,642
Total	159,196	355,469

from 1914 to 1925. In considering the effects of these treatments it is worth recalling that it was only in 1917 that all treatments were given under personal supervision and that it was only in 1919 that any real attempt was made to develop the sanitary program along with the

treatment. Following this the second treatment campaign was started in Veraguas in 1921 and transferred to Cocle in January 1922. Some idea of the extent to which the treatment work has kept down the level of infestation can be gained from our analysis in a later section of this report. One of the greatest difficulties which is constantly noted by the field directors was to get the people to return for treatments beyond the first. An example of this is shown by a summary of the treatments given in districts completed during one year (1922), during which 34,324 treatments were administered in ten districts in three different provinces. Of these 13,732 were first treatments, 10,358 second, 6,548 third and 3,532 fourth.

4. *Development of the sanitary work.*

In the control campaign in Panama the sanitary phases of the program were slow in developing. In a summary of the situation at the end of 1917 the statement is made that latrine installation had not kept pace with examination and treatment. In Panama City most of the houses had sewerage connections and in David and Chitre about 30 per cent. of the houses had latrines. In the smaller towns of the interior it was estimated that less than 10 per cent. of the houses had latrines and in the rural districts they were unknown. Real progress on this phase of the work was made possible when on September 12, 1919 the government promulgated a decree requiring the construction of sanitary latrines. This stimulated the work of construction and during 1919, 423 latrines were built for private houses. The further development of this part of the program is shown by the fact that 915 latrines were erected during 1920, which was more than twice the total number built in the first five years of the campaign. With the attempt at a program of presanitation which came in about this time, two problems of great importance developed, viz., the problem of preventing the breeding of Culex mosquitoes in the latrines and that of conserving the latrines in places where they had been built. During the rainy season water would collect in the pits and the whole sanitary program was attacked from the standpoint that the introduction of latrines was increasing mosquito breeding and spreading malaria. Much time was spent in investigating and refuting this charge, and a systematic arrangement for oiling was made wherever it seemed necessary. Along with this developed the system of sanitary inspection to which a constantly greater proportion of the effort was given.

In 1921 an adequate inspection service had been established in the

province of Veraguas where all the work had been concentrated. On January 1st two sanitary inspectors were appointed to devote their whole time to the work of inspection, and in addition each technical assistant was required to inspect each week all the latrines existing in his district. The results of the inspections were entered on cards which were nailed on the doors of the latrines, and entered on a suitable blank in the inspectors book. Each latrine containing water was oiled each week. During the first three quarters of 1921, a total of 21,868 inspections were made in this province, which resulted not only in maintaining in sanitary condition the latrines constructed during the year, but also in putting into sanitary condition a large number of those previously constructed. This was the beginning of the inspection system which has been not only maintained in the districts completed after 1921 but which was extended to each new area in which the work was taken up.

The later reports show a constant extension of this system. For example, during 1923 a total of 6,061 houses was added to the sanitary census of which at the beginning only 9 per cent. had latrines, and 3,144 houses were provided with latrines or an increase of 51.9 per cent. in the areas covered. By the end of 1926 the number of dwellings in charge of inspectors was 23,150 of which 73.7 per cent. had latrine accommodations. During this year 2,650 new latrines were constructed and 84,889 inspections were made. It would take too long to go into all the details of this phase of the campaign work. During 1926 ten sanitary inspectors were employed by the Department of Uncinariasis and by the end of the year three additional government inspectors were at work. The system is being constantly extended and promises well for the permanency of the work of the department.

5. *Summary and general discussion of the campaign.*

The outline of the development of the hookworm campaign in Panama has more than local interest since it shows the effect on a single situation of the progress of ideas on hookworm control which came during the last decade. It is easy now in the light of greatly increased knowledge to point out the mistakes of the early years. The high level of infestation made Panama a particularly poor place for dispensary treatments without sanitation, and from what we know now it seems certain that the treatments of the first few years have had little permanent result except in educating the people. Lasting results seem to have been obtained only with the introduction of pre-sanitation, mass treatment and a follow-up system of sanitary in-

spection. The present procedure seems to be sound, and if there is no let down in the sanitary inspection system great improvement may be expected in the future. Our studies of the present hookworm infestation of Panama areas which have undergone campaign work show definite reduction, wherever sanitation has been stressed even where the sanitation is only partial. They show, however, the difficulty of the problem since the degree of hookworm infestation in such areas is still quite great. They further illustrate the dangers of reinfection wherever sanitation is not well carried out. While many years of constant vigilance will be needed to reduce hookworm infestation in Panama to the point where it will cease to be a public health problem, the foundations for future work are securely laid and the value of the methods used has been adequately demonstrated. The work of the Department of Uncinariasis has further succeeded in making a good beginning in instilling into the people of Panama some of the elementary principles of sanitation, and has brought about the recognition of governmental responsibility for the improvement of the health of the people.

D. Hookworm incidence found in the Republic of Panama during the course of the campaign.

1. *General incidence of hookworm in Panama.*

As already noted most of the fecal examinations during the course of the campaign were made by the smear method which was well carried out since several slides were examined before a case was called negative. Probably few cases with more than 500 eggs per gram would be missed by this method (see Hausheer and Herrick, 1927), and on account of the intensity of the infestation the figures of incidence given in the reports for untreated groups are probably only slightly below the real incidence. Table 2 gives the record of the examinations made before treatment in provincial Panama for each year through 1926. During this same period 35,295 examinations were made in the City of Panama of which 18,255 were positive making a percentage of hookworm infestation of slightly over 50. No egg counts or worm counts are available to compare the rural infestation quantitatively with that of Panama City but the greatly lower percentage and the actual situation known to exist there suggests that the degree of infestation is very much lower in Panama City than in the rural districts. The findings in Panama City probably indicate what would also be found in the city of Colon. The reports for provincial Panama

cover practically the whole country and show an unusually widespread high incidence. One exception to this was found by the Caldwells' (1926) among the San Blas Indians where in a series of 595 examinations only 28 or 4.7 per cent. were found infested. This low infestation is thought by these authors to be due to the habit of defecation in the sea and would probably apply to most of the San Blas Indians who live on the seashore.

TABLE 2.

Incidence of hookworm infestation in provincial Panama as shown by the examinations made during the work of the Department of Uncinariasis.

Year.	Persons examined.	Infested with hookworm.	Per cent. infestation.
1914	2,381	1,960	83.1
1915	22,901	15,970	70.0
1916	28,813	23,764	82.0
1917	20,578	18,570	90.2
1918	9,195	7,977	86.7
1919	12,219	11,439	93.6
1920	8,796	8,362	95.0
1921	10,620	9,291	87.5
1922	15,672	14,862	94.8
1923	6,088	5,736	94.2
1924	1,534	1,336	87.0
1925	3,874	3,358	95.6
1926	3,731	3,557	95.3
Total	146,402	126,182	86.1

The real hookworm problem of Panama, therefore, is represented by the 86 per cent. found positive in the 146,402 examinations made in the interior. When it is considered that practically every accessible populated region was reached by these examinations and that every province was well covered except Darien and the Intendencia of San Blas, which are only inhabited by scattered Indian tribes, it can be seen that these statistics can be taken as representing an adequate picture of the incidence of hookworm in rural Panama. It will be remembered that beginning with 1921 certain areas which had been covered with the earlier treatment campaign were again surveyed. The high percentage found after this date indicates that the incidence at least had not been influenced by the previous treatments, so that these figures will be included in the further analysis on the same basis as those of the earlier examinations. The large reduction in the number of yearly examinations made after 1922 was brought about

by the introduction into much of the campaign work of the policy of treatment without previous examination. In the various reports some analysis of the incidence statistics is made on the basis of locality, sex, age and race. We will, therefore, utilize some of this information in attempting to determine variations in the incidence according to these factors.

2. *Variations of hookworm incidence according to locality, race, age and sex.*

The chief factors which produce differences in hookworm incidence in different population groups of provincial Panama appear to be related to rainfall and to the extent to which the people live in town or in strictly rural communities. We have already seen that the incidence in Panama City is very much lower than in the interior. Information is not available for any extensive comparisons of incidence in towns of various sizes as compared with strictly rural communities. There is only a slightly lower incidence in districts including some of the largest towns of the interior than in those with smaller villages in strictly rural areas. An exception to this is the district of Bocas del Toro where examinations made in the early part of the work showed an incidence of 35.1 per cent. in 2,106 examinations. In the same province Almirante, Guabido and Bastimentos showed an incidence of slightly over 50 per cent. Bocas del Toro and Bastimentos are on islands and Almirante and Gubadio are well to the north of the province in a region of comparatively low rainfall where the length of the rainy season is much less than in other parts of Panama. The district of Chiriqui Grande in the same province which showed an incidence of 76.8 per cent. in 612 examinations is further to the south in a region more like that of northern Chiriqui. The district including the city of David in Chiriqui province showed an incidence of 75 per cent. while near-by rural districts ranged from 90 to 98 per cent.

It would hardly be worth while to analyze in any detail the differences in incidence shown in different districts and different provinces except to point out that there is a contrast between the coastal plain region as represented by Cocle province with an incidence of from 69 to 79 per cent. and the highland region of Veraguas and Chiriqui where the incidence is almost always well above 90 per cent. This can apparently be accounted for by the somewhat lower rainfall of the coastal plains region, and is brought out more strikingly by the differences shown later in the report in the egg counts from the Penonome district and the Santiago district. All in all the incidence

statistics from the records of the Department of Uncinariasis show an extraordinarily high incidence of hookworm infestation throughout provincial Panama both in the towns and in the county, and interpreted by the egg count records which are analyzed in the later sections of this report place Panama as one of the most intensely hookworm infested counties in the whole world.

Throughout the reports the incidence statistics are analyzed according to race. In the report for 1920 the examinations up to December 31 of that year including 78.3 per cent. positive out of 121,697 examinations are analyzed according to race (Table 3). If the

TABLE 3.

Hookworm incidence in Panama according to race as shown by examinations made up to December 31, 1920.

	Number examined.	Number infected.	Per cent. infected.
All races	121,697	95,274	78.3
White race	10,743	6,589	61.3
Brown race (Mestizo), chiefly mixture of Spanish and Indian with Negro blood in some places	91,722	75,964	82.3
Black race	9,383	5,168	55.1
Red race (Indians)	8,214	6,435	78.3
Yellow race (Chinese)	161	62	38.5

figures on this table are taken without further analysis it might be considered that there were definite racial differences. The "brown" race or mestizo mixture and the Indians of the mountain regions represent most typically rural Panama where the conditions for the spread of hookworm infestation are most favorable. The few Chinese examined are almost all merchants, a class which is not so much exposed to infection. The whites usually contain a larger percentage of well to do people and city dwellers and therefore show a lower incidence. The blacks in this series contain a considerable proportion from the places on the Atlantic coast and from Panama City where the hookworm incidence is in general lower. Where negroes are equally exposed to infestation they show an incidence as high as the mestizos and Indians. This is shown in some of the later reports where negroes from the rural districts of the Pacific littoral are listed separately. The 2,538 negroes listed from these regions of high hookworm infestation show 95.5 per cent. positive. It can be

seen, therefore, that the statistics from Panama show no difference in hookworm incidence that can be interpreted as dependent on race.

The analysis of the incidence statistics according to sex show no constant differences. The differences in degree of infestation in the sexes which are shown in our egg count analyses are obscured when incidence alone is considered. The differences in degree of infestation between the different age groups are also almost entirely obscured since the infestation is so widely distributed in all ages. An exception to this in Panama City where the figures show that the 0–5 group has a much lower incidence than the older groups. The egg count series given in later sections give a truer picture of the differences in the hookworm infestations between the children and the adults.

E. Description of the areas studied in the summer of 1926.

1. *Introduction.*

As noted earlier about 80 per cent. of the provincial population of the Republic of Panama lives on the Pacific littoral either on the coastal plains or in the low foothills. It was natural, therefore, that localities representative of this region should be chosen for the investigations we proposed to make on hookworm disease in the summer of 1926. The objects of our studies were to obtain information on the hookworm situation in Panama and the effect which the control campaign had had on the degree of infestation. It was, therefore, important to have a headquarters from which we could reach areas in which the original situation was unchanged and which were as typical of the conditions of life of as large a proportion of the people as possible. Also it was necessary to have areas within reach in which control work of different degrees of effectiveness had been carried on at different times. The choice of Penonome as headquarters proved to be a very happy one because near it were areas typical of both the plains where cattle raising is the principal industry and the foothills where agriculture is the chief occupation. Also from here could be reached in a few hours the Santiago region, where the rainfall is much greater, and the character of the population different. Also near these two centers could be found groups of people who had been subjected to widely varying degrees of control work in regard to both treatment and sanitation. As finally carried on our studies covered population groups representing eleven different localities. From these groups a total of approximately 2,250 different individuals were examined by the dilution egg counting method. These egg counts were supplemented by studies of soil pollution and soil infestation,

so that we are able to present a picture for each group of the factors contributing to the present hookworm situation. In this section we will give a detailed description of these areas and will include also for them the earlier information on hookworm infestation and the records of the control work that had been done. These descriptions, then, will form the background for the understanding of the conditions as they were found during our studies in the summer of 1926 and will need to be referred to constantly in connection with the later sections of this report.

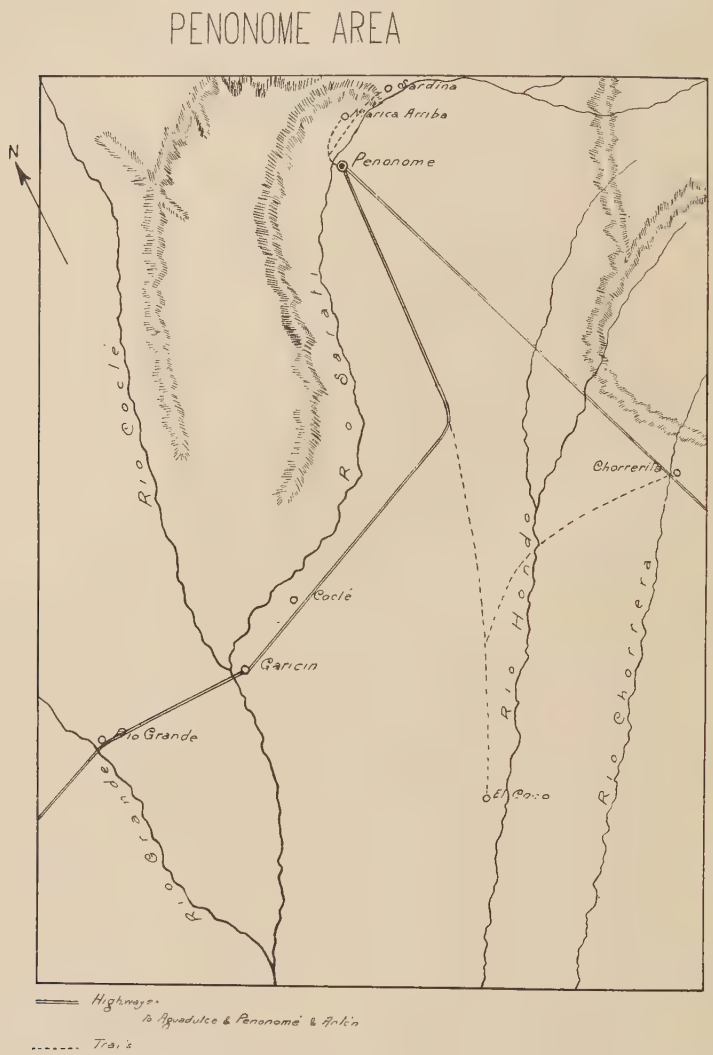
2. *General discussion of the areas studied.*

The people of the two zones selected for our hookworm investigations, the Districts of Penonome, Province of Cocle, and the District of Santiago, Province of Veraguas (Map 1) are representative in living conditions, occupations and racial types of about 85 per cent. of the provincial population of Panama. The District of Penonome occupies approximately the central part of the coastal plain of the Province of Cocle, from the low hills of the mountain range to the north to the confluence of the Rio Grande and Cocle rivers. Eighty per cent. of the population of Cocle Province lives in this coastal plain, which extends the full length of the province and has a width of from 15 to 30 miles. It consists of a rolling plain, with very sparse vegetation and is used principally as grazing land for cattle. The average yearly rainfall of this region is estimated to be between 60 and 70 inches.

The Penonome zone includes (Map II) the following places where we made studies: the town of Penonome, which is the provincial capital; the two adjoining villages of Sardina and Marica Arriba, which are located along the first rise of the foothills; another group of villages, Rio Grande, Garicin and Cocle which lie along the main highway between Penonome and Santiago in the open pasture plain and form contiguous communities of scattered houses for the cattlemen and their families; and finally the communities of Chorrerita and El Coco, the houses in which are so scattered that they form what are called in the United States townships rather than definite villages. In fact except for Penonome all these communities are widely scattered and in them the real unit is the separate house or group of two or three houses.

About 75 per cent. of the residents of the town of Penonome are engaged in commerce and 25 per cent. in agriculture, particularly grain cultivation. The inhabitants of Sardina and Marica Arriba are

truck gardeners and grain farmers while those of Rio Grande, Garicin, Cocle, El Coco, and Chorrerita are principally engaged in the cattle



MAP II. Penonome area showing the location of the places where studies were made.

industry, although raising some grain and vegetables for individual consumption.

The district of Santiago, including the town of Santiago and the villages of La Atalaya and La Soledad, lies along the main highway connecting the provinces of Cocle and Veraguas (Maps I and IV). These are typical upland communities differing markedly from those in the Penonome district, in soil, rainfall vegetation and in the racial character and occupations of the people. The people of the town of Santiago are generally merchants usually on a very small scale, although about 40 per cent. of the men work occasionally as day laborers on nearby farms. The people of La Atalaya and La Soledad except for a merchant group in the first place farm small plots of grain, vegetables and fruits and also raise fowls and hogs. La Atalaya and La Soledad differ from the small communities studied in the Penonome district in that they are definite villages, each formed of houses grouped around a square with others more widely scattered. The population of this region is distinctly different from that of the Penonome district since in Santiago and the surrounding region the white blood predominates while in the country around Penonome the population shows a marked infusion of Indian and negro blood. The rainfall of the Santiago region is over 100 inches a year and with a rich clay loam soil and vegetation is quite abundant especially in the yards and near the houses.

3. *Description of the individual areas.*

a. The town of Penonome.

The town of Penonome (Maps I and II), the capital of the Province of Cocle, lies at the eastern end of the extensive coastal plain near the base of the Santa Cruz and Los Pavas hills. The Zarati river encircles half the city. It has a total population of approximately 1,800, the predominating racial type being the moreno (mestizo) with a pronounced infusion of Indian and negro blood. The town is composed of about 435 dwellings, the majority of which are quincha structure (stud frame and clay reinforced with straw) roofed with tile or zinc. On the outskirts of the town there are still found some houses with thatch roofing in which the poorest families live, but their number is slowly decreasing.

The cattle industry and commerce form the principal sources of revenue for the population. Many of the men are employed as laborers by the land and cattle owners, while numbers of the women work as servants or wash women. The percentage of the population engaged in agriculture is comparatively small. There is, however, a

constant influx of people into the town from the rural districts, so that in any series of examinations there are included some who have only lived for a short time under the urban conditions, and whose hookworm infestation is really representative of the particular rural districts from which they came.

In 1916 the Department of Uncinariasis conducted a hookworm campaign in this district for several months with a central laboratory established in Penonome. The results are questionable as at that time the treatments were usually given to the patients to be taken at home and the number of treatments distributed does not indicate the number of persons actually treated. In 1922 the Department of Uncinariasis returned to Penonome with a semi-intensive curative campaign, at the same time enforcing the construction of sanitary latrines for every house. At the end of that year at least 75 per cent. of the total number of houses was provided with latrines, and 35 per cent. of the population had been treated. The percentage of hookworm infestation found in this survey was 88. A provincial sanitary inspector remained in charge of the permanent sanitation, directing the conservation of the latrines, the construction of new latrines and the administration of treatment to patients seeking it. In the summer of 1926, 90 per cent. of the houses had latrines which were reported by the sanitary inspector to be 100 per cent. in use.

b. Sardina and Marica Arriba.

The villages of Sardina and Marica Arriba are situated approximately two miles to the east of the town of Penonome (Map II). The soil is a dense red and brown clay covered with a varying layer of loam. The topography is somewhat broken by shallow ravines and hillocks. The houses are scattered along a wide horse trail (Map III), each house consisting of the main building of one or two rooms and generally a lean-to serving as a kitchen and storeroom. The houses are set in small cleared areas with cultivation or rank tropical growth within 5 to 10 yards. Fruit trees are usually found close to or adjoining the houses. All are built of quincha, roofed with home-made tile or thatch and are small and low with packed earth floors and lack any provision for ventilation.

The census showed that there were 121 people in each of these villages. They are mestizos with the Indian type predominating though there is an apparent infusion of negro blood in Marica Arriba. Agriculture is the chief occupation, grains and vegetables being produced and sold in the town of Penonome. The economic status

MAP III. Sardina and Marica Arriba showing the location of the individual houses.

of the people is better than in any of the other groups studied and they are unusually well nourished, most of them having meat daily. Their high economic status is the result of the extent to which they raise various vegetables and grains and the ready market they have in the nearby town of Penonome.

Though hookworm dispensaries were never conducted in Sardina and Marica Arriba some of the people were treated in Penonome during the campaign of 1922. During 1925 and the spring of 1926, 20 latrines were built in the village of Sardina for 21 of the 27 dwellings, all of which were apparently in use at the time of our visits, particularly by the adults. Marica Arriba was not sanitated and, with the exception of the few individuals treated, offered a study of hookworm infestation under unmodified conditions. In fact Sardina offered the same type of situation since the length of time the latrines had been in use was not sufficient to appreciably reduce the hookworm infestation.

c. El Coco.

The village of El Coco is south of Penonome in the coastal plain along the river bottom lands of the Rio Honde (Map II). The soil over this area is quite sandy with an intermixture of clay. The houses are similar to those of the other areas. They are widely scattered and one or a few houses rather than a larger group form the unit. Animal husbandry is the principal occupation and there is almost no cultivation of the soil. Some of the families, however, maintain garden plots up in the hills, where they cultivate vegetables and grain. There are few trees or other vegetation around the houses, the situation in this respect being comparable to that of Rio Grande. A laboratory and dispensary were stationed here for one month during 1922. At this time 97 per cent. hookworm infestation was found and 133 patients were treated of a population of 230. No latrines had ever been constructed except one at the school which was not in use. The people are very poor, of an Indian-negro (mestizo) mixture, there is almost no wearing of shoes and most of them are undernourished.

d. Chorrerita.

The village of Chorrerita is scattered along the road between Penonome and Anton (Map II). It is situated in the coastal plain, but near its edge and the country is more hilly than that around El Coco or Rio Grande. Chorrerita is really a township in our sense rather than a village since its 63 houses are scattered over an area of more than 25 square miles. The isolated house or at most groups of

two to four houses constitute the real unit, from the point of view of hookworm dissemination at least. The soil is chiefly a clay with in some places a mixture of sand. Some of the houses have enclosed yards with gardens and fruit trees. There is usually to be found some scattered cover either of trees or bushes within short distances of the houses. Some of the people are engaged in animal husbandry but the majority make their living by the cultivation of vegetable, fruits, and grains. Some of the people are extremely poor and undernourished, and all live on a rather low economic plane. The roofs of the houses are almost all of grass thatch, and the walls are of mud or grass thatch. In most cases they consist of a single room with a lean-to or detached shed for cooking. Not uncommonly the kitchen is a smaller hut, used also as a sleeping room for part of the family. The floors are of packed dirt which are kept fairly well swept. There is practically no wearing of shoes whatever. No hookworm campaign has ever been conducted at Chorrerita although a few people of the area have sought treatment elsewhere. None of the houses at the time of our investigation were supplied with latrines.

e. Rio Grande, Garicin and Cocle.

The villages of Rio Grande, Garicin and Cocle, which form another unit of the Penonome area, lie along the highway that runs from Penonome to Santiago (Map II). The types of houses and the habits of the people are much like those of the other villages of this district already described. The houses of these communities are widely scattered along both sides of the road, each community forming a township rather than a village in the sense we use the word, and there is no clear cut division between the three places. The extensive level plain which these villages occupy serves as pasture for numerous cattle, since cattle raising is the chief industry of the region. Trees or other cover around the houses are very rare making these communities more open than any of the others studied. The majority of the people are poor and there is practically no wearing of shoes. A laboratory dispensary was stationed at Rio Grande and Garicin for more than a month in 1922. The records of this dispensary show that of the 481 persons examined from a population of 667, 95 per cent. were infested with hookworms. Of these 297 were treated and some of the inhabitants of Cocle were also treated at Penonome and Rio Grande at about this time. Sanitary work was carried on in Rio Grande in 1923, one year after the treatment campaign and by the end of 1924 latrines had been built at 82 per cent. of the houses.

Later in 1924 and 1925, two to three years after treatment, the sanitation work was taken up at Garicin and latrines were built at about 60 per cent. of the houses. The houses in Cocle are entirely without latrines.

f. Santiago.

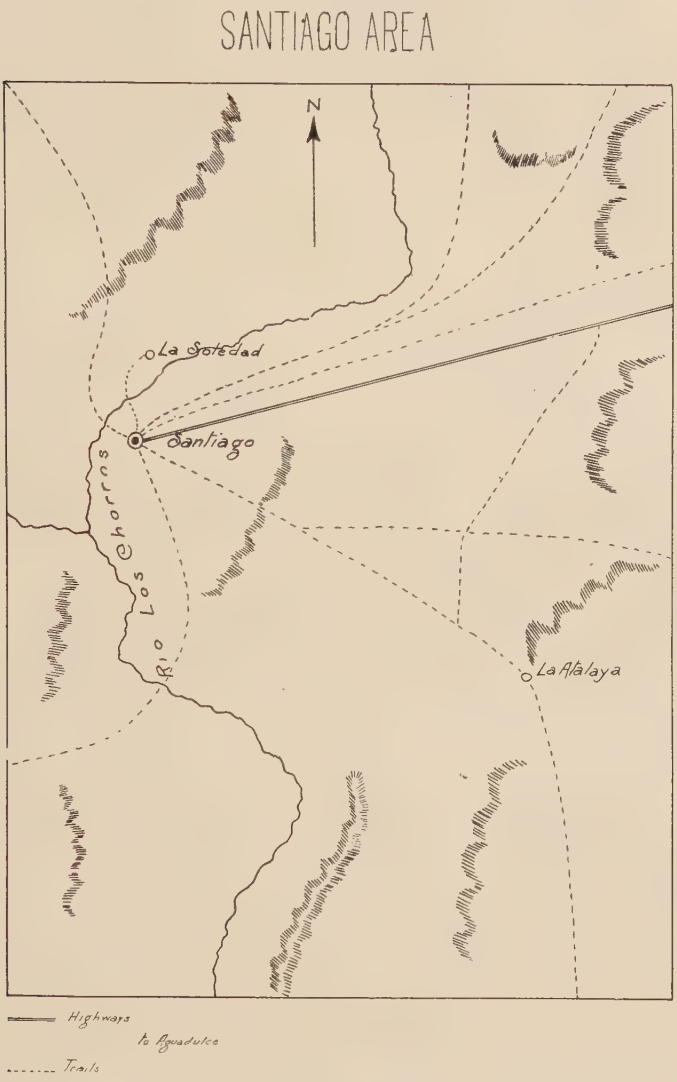
The district of Santiago, in the Province of Veraguas (Map IV), is typical of the upland regions, with a heavy rainfall (more than 100 inches a year). The soil of the region is a rich clay loam and the vegetation is much more luxuriant than that in the Penonome district except for Sardina and Marica Arriba. The people are of lighter complexion than most of those of the Penonome area and are mostly mestizos of a predominating Spanish type.

Santiago, capital of the Province of Veraguas, is situated on a wide extension of level ground, surrounded by the La Atalaya and Los Algarrobos hills and has approximately 1,000 residents. The predominating type of building is that of quincha finished with a coat of cement and whitewashed with lime. The old Spanish form of tiles are employed for roofing. These buildings are being abandoned slowly and are replaced by those of native lumber and galvanized iron roofing. Santiago serves as the commercial center for the eastern half of the Province of Veraguas. It is estimated that at least 50 per cent. of the city's population are engaged in agriculture and the remainder in commerce or are domestics and laborers. All the dwellings have patios, grass grown and cultivated with cane, coffee and fruit trees. Chickens and ducks, raised by almost every family have free access to every part of the house, and pigs are still found in some back yards resting and splashing in big muddy pools.

During 1920 the Government drilled five wells to provide the town with pure water. Before that time water for all domestic purposes was taken from open wells and also from a considerable number of shallow wells or excavations, some of them only a foot deep, dug along the small water courses at the outskirts of the town, or at any other low place where there was a probability of obtaining water. These were constantly polluted by surface washings. The town has no service for garbage collection and disposal with the result that garbage and rubbish are promiscuously dumped on deserted streets or scattered in the yards to fertilize the ground for the growing of grass, cane, coffee, and fruit trees.

In 1918 a preliminary hookworm survey was made here of a sample population of more than 300 persons which disclosed about 94 per cent. infestation. A laboratory unit was established during 1919 and

approximately 60 per cent. of the residents were treated. Latrine construction was commenced at the end of this year and by March



MAP IV. Santiago area showing the location of the places where studies were made.

1920, 70 per cent. of the homes were provided. A reinspection, six months later disclosed that fifty per cent. of these had been demolished or abandoned and that the majority of them were not in use. In view

of this situation a permanent inspection service was established, with the result that at the present time 80 per cent. of the homes have latrines. The sanitary inspector maintained for this service administers hookworm treatment to volunteer patients. Since 1920 the school children have been treated twice, the last time during 1924. Most of the group included in the examinations that we made from Santiago in the summer of 1926 were from the poorest parts of the town. They were as a whole undernourished and crowded. The yards were very small and the young children confined to their yards or to the streets.

g. La Atalaya.

The village of La Atalaya is situated at a distance of about 8 miles to the southeast of the town of Santiago (Map IV). It occupies an area of two square miles of level ground surrounded by a chain of low hills. A motor road passable throughout the year connects these towns. The village consists of about 77 houses, half of which form a rectangular square about a central plaza and church and the remainder, mostly huts, are scattered over the plain (Map V). The inhabitants, which numbered at the time of our work 268, are classified as 25 per cent. white and the remainder mestizos of Spanish and Indian types. The dwellings are similar to those described for the other villages, but most of them are larger and of better construction. They have large cultivated patios containing cane, coffee and fruit trees and often ornamental flowers. The principal industry is the raising of pigs, poultry and grains for local consumption and sale in the markets of Santiago and Aguadulce. The economic condition of these people is better than that of the other villages of this province and comparable to that of Marica Arriba and Sardina in the Penonome district.

A preliminary survey of La Atalaya during 1918 gave a hookworm incidence of 98 per cent. A laboratory and dispensary conducted a campaign during the latter part of 1919. At the same time latrine construction was enforced for the homes surrounding the plaza. Of the 77 dwellings, 53 or 68 per cent. are now provided with latrines. During the course of the dispensary 202 individuals were treated and 109 or 54 per cent. were discharged with two treatments.

This village really offers two contrasting groups of people, i.e., those around the central square where most of the houses had latrines and where most of the treatments were given, and those in the outlying houses where there are few latrines and where few were treated (Map V). A considerable proportion of the people living around the central square are engaged in commercial pursuits, and are better off economically than the others.

MAP V. The village of La Atalaya showing the distribution of the houses.

h. La Soledad.

La Soledad, a village about three miles to the north of Santiago, consists of a group of 46 houses placed irregularly about two well-defined squares which serve as community pastures (Map VI). The houses are quite primitive, constructed of cane or thatch with thatch

roofs and mud floors. The patios are fenced, grass covered and usually contain shrubs and trees. The amount of vegetation in and around these yards is greater than at any of the other places in this series, and gives this village more that aspect which we are accustomed

MAP VI. The village of La Soledad showing the distribution of the houses.

to associate with tropical communities. The soil is a sticky yellowish clay.

At the time of our work in La Soledad it had a population of 194 people all of whom would be classified as mestizos with the characteristics of the white race predominating. Agriculture is practically the only industry, grains and vegetables being cultivated on a small scale for local consumption and for sale in Santiago. Some of the

people cut firewood for the Santiago market. It will be noted that while there is no such concentration of houses in La Soledad as around the central square in La Atalaya, it is a true village, with the houses not nearly so much scattered as in the rural communities of the Penonome district. The yards of many of the houses are contiguous, and there is a considerable intermingling of the people. Here then the village rather than the house or small groups of houses must be considered as the unit.

During 1919 and 1920, 77 of the residents of La Soledad were treated for hookworm. No sanitary campaign was carried on at that time and the houses are entirely without latrines.

i. Summary of areas.

These areas represent the types of conditions under which the great majority of the provincial population of Panama live. They also represent a variety of differences in amount of hookworm work, which had been completed before our survey. This makes possible the analysis of the effect of the different control measures as applied in Panama in reducing the level of infestation. In presenting this material there will be gathered together in one section all the information obtained on the degree of infestation and the factors influencing the spread of hookworm where the conditions had not been appreciably influenced by the control work. In another section an analysis will be made of the effect of the control program on the level of infestation as applied in the different areas studied. In addition a section will be devoted to a discussion of the data available on the relation of the hemoglobin indices of the people of rural Panama to the degree of their hookworm infestation. In this way all the data available will be included in one connection or another and as complete a picture will be drawn of the present hookworm situation in Panama as is possible from the information that we gathered. Besides these sections this report will include a section on the methods used, another on stool size in relation to the egg count, a section on the use of a standard population for correcting statistical data, and a final one on the epidemiology of ascariasis and trichuriasis.

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II. LABORATORY METHODS IN THE PANAMA STUDIES.

By

N. R. STOLL.

Outline.

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A. General methods used.

The field laboratory for the 1926 summer's work in Panama, which ran for about four months, June to October, was situated at Penonome, the capital of Cocle province. The routine technics employed were centered on two needs, the isolation of infective hookworm larvae from the soil, and the demonstration and counting of parasite eggs in the feces, with special reference to hookworm. Besides the investigators, who examined all of the larval isolations and participated in most of the egg counts, there were three full-time technicians. Two of these latter became reliable egg counters, and assisted primarily in this phase of the work, while the third cooperated with one of the sanitary inspectors of the district in securing specimens from the various communities under study.

Certain information concerning the methods and results from the laboratory unit are not only of value in connection with the ultimate use made of our own data in the succeeding sections of this report, but may also be of interest to other workers using similar laboratory methods.

For the isolation of larvae the Baermann apparatus was employed, as earlier described by Cort, Ackert, Augustine and Payne (1922) and Cort, Stoll and Grant (1926). Inasmuch as no modifications were introduced either in the field collection of soil samples or their handling in the laboratory, further discussion concerning them need not be given here, except to state that the Baermann isolation method functioned satisfactorily under Panama conditions.

Altogether fecal examinations were made of a fair sample of the

people of ten "villages," situated up to sixty-five miles from Penonome. Most of the specimens for examination were secured by the following method. The sanitary inspector or his assistant would take a census of all the inhabitants in an entire, or an arbitrary portion of a community, and leave a sufficient number of half-ounce tin containers appropriately labelled, for the members of each household. These tins were collected on the following day and transported to the laboratory, return trips being made on succeeding days for any that were at first unfilled, until a sufficiently large proportion of the available population had furnished fecal specimens. By this method upwards of 90 per cent. efficiency in collection of specimens was obtained for some areas. Hemoglobin readings, using the Talquist scale, were made on some of these trips.

Besides the above collections there came to the laboratory as the summer progressed an increasingly large number of individuals requesting examination for parasites. The specimens from these people augmented the total Panama series appreciably.

In the examination of feces, egg counts were made by the dilution method (Stoll, 1923), using displacement and small drop (Stoll and Hausheer, 1926). Specimens negative by the routine dilution count were examined by the Willis technic for the presence of small numbers of eggs.

Examinations for ova were made as promptly as possible after securing the fecal specimens. Inasmuch as the greater number of containers were collected on specified days by the sanitary inspectors in charge at the various villages, it was usual for the laboratory to receive a considerable quantity of material at a time. In order to hold the fecal samples so that the ova would not develop at the tropical temperatures, an icing arrangement was devised. Two large packing boxes of such size that the smaller nested in the larger, were held in position by packing the space between them with excelsior. A thin layer of cement for covering the bottom of the inner box, together with a drain pipe, and a double cover on hinges completed this serviceable refrigerator. Ice was available in Penonome. Comparative egg counts made on specimens before and after ten days of refrigeration indicated no loss in ova. An analysis of our records shows that 40 per cent. of our specimens were tubed within one day after the feces were passed. The average length of time for all specimens was $2.55 \pm .03$ days.

As in our previous studies, all fecal samples were classified as to consistency of the stool in order to bring counts for analysis to a

"basis of formed feces." When first proposed by Stoll (1924) a classification of "formed" (F), "mushy" (M) and "diarrheic" (liquid) (D), was used. Hill (1926) has shown that there is an allowable intermediate class between the formed and mushy consistencies, which he has designated "soft formed," SF. Such an interpolation logically demands the use of an additional type between mushy and diarrheic, which we adopted in Panama as "MD." Accordingly counts have been reduced to a formed stool basis by multiplying F counts by 1, SF by $1\frac{1}{2}$, M by 2, MD by 3, and D by 4. A discussion of the validity of such a procedure is given in the next section.

At the end of our summer's work a summary was made of the classifications given to over 3,300 of the stools examined in Panama. This showed that 15.5 per cent. were classed as F, 16.0 per cent. SF, 60.4 per cent. M, 6.4 per cent. MD, and 1.7 per cent. D. It is possible to make a conjectural comparison of how these would have been classified on the original F, M, D grouping by allocating one half of the SF specimens to the F and M groups, and one half of the MD to the M and D. Thus considered our Panama specimens would have shown 23.5 per cent. F, 71.6 per cent. M, and 4.9 per cent. D. Of 1,638 random China specimens similarly classified 44.4 per cent. were F, 47.9 per cent. M and 7.6 per cent. D. The differences in the percentages in the two major groupings corresponded well with the general observations made in both Panama and China as to differences in foods, etc.

The occasion of securing a relatively large series of counts by displacement and small drop gave an opportunity of scrutinizing various phases of this method. Information of interest was also obtained on the Willis technic from the standpoint of realizable results in a field laboratory.

B. Routine dilution egg counting.

It will be recalled that the dilution egg counting method is essentially a simple procedure, whereby a known amount of fecal specimen is comminuted at a 1 : 15 dilution with decinormal sodium hydroxide in a closed container. Following this a small known sized drop of the mixture, namely 75 cu. mm. (0.075 c.c.), withdrawn after sufficient shaking to evenly distribute the eggs, is removed promptly, placed on a slide, covered, and all the ova counted with the aid of a mechanical stage on the microscope. Under these conditions, multiplying the average egg count per slide by 200 or the sum of the two drops usually counted by 100 gives the number per c.c. of original feces.

The technic as originally described recommended weighing the feces to be used, although in field studies there is evidently a gain in time by using displacement instead. For this latter purpose special Pyrex flasks are used (figured by Stoll and Hausheer, l. c.) which are merely 50 c.c. Erlenmeyer flasks with elongated necks upon which are engraved lines at the 56 and 60 c.c. levels. The decinormal sodium hydroxide * is added to the lower mark, feces put in until the fluid reaches the upper mark, and then beads and a rubber stopper added to assist in comminution.

As a generality it may be stated that this displacement option with the flasks worked very well. Comminution was effective, and the convenience of the equipment was marked.

For tubing the specimens bamboo splints were employed (ordinary swab sticks also worked excellently), and with care there was little soiling of the necks of the flasks. Proper tubing of the specimen also requires that the meniscus of the clear diluent have the same relation to the 56 c.c. level, that the mixture with feces added has to the 60 c.c. level. Our routine called for the tubing and a preliminary shaking to be performed in the afternoon, and the final comminution in the tube and subsequent counting of the slides next day. In shaking, either to break up the feces or to obtain a fair distribution of eggs in the mixture before withdrawing the drop for counting, the tube was so held in the hand as to throw the beads toward the rubber stopper rather than against the flat bottom of the flask.

There was no breakage in the routine use of these displacement flasks except through the carelessness of the dishwasher who had the bad habit of crowding the space in a small iron sink with too many flasks, thus occasionally crashing them against the metal fixtures.

* Decinormal, or tenth molar, sodium hydroxide is approximately a 0.4 per cent. solution (4 grams of technical caustic sticks made up to one liter with water). It came to our attention in Panama that inadvertently some workers were using this technic with what was really a twice normal or 8.0 per cent. solution. With this mixture it can easily be demonstrated that there occurs loss of ova. Thus 6 tubes made up comparatively with the proper decinormal and the improper solution 20 times its strength, showed that such a mistake caused a loss of 87 per cent. of the hookworm eggs compared to routine conditions. Lane (1927) has recently theorized on the danger of using even decinormal sodium hydroxide in the dilution technic for hookworm ova by citing the action of 4.5 and 15.0 per cent. caustic solutions on adult nematodes. Such surmises would hardly appear to be evidential on this point as the solutions mentioned are respectively 11 and 37 times the strength of the proper decinormal solution. One would not presume, for instance, to interpret the action of normal saline (about a one per cent. solution) on hookworm ova, by noting the marked destructive effects upon either eggs or worms of a saturated sodium chloride solution over 26 times its strength.

A tabulation of breakage from this source showed, after twelve weeks, loss at the rate of 7 flasks per thousand washed. This, in our opinion is greater than need be.

We have come to prefer $1\frac{1}{2}$ x 3 inch slides for the microscopic work, as being superior to either the ordinary 1 x 3, or the larger 2 x 3. For covering "small drops" either 25 mm. square or 22 x 30 mm. covers were employed, the latter being somewhat preferable. The magnification used for examining slides, has been uniformly a 16 mm. objective, with either a 10×, $7\frac{1}{2}$×, 6× or 5× ocular. In training technicians we prefer the 10 x 16 mm. combination, giving a magnification of about 100 diameters. As experience is gained in the easy recognition of the typical ova encountered, and accuracy gained in the counting, one of the other oculars has been ordinarily used. The writer prefers a $7\frac{1}{2}$× ocular (giving about 75 diameters) but most of the workers in the Panama laboratory eventually used the 5× ocular, with a resulting magnification of about 50 diameters. In the latter case especial care needs to be taken not to miss trichuris ova.

During the period of about 17 weeks that the Panama laboratory unit was functioning, something over 3,500 egg count tubes were examined, or slightly more than 200 per week. A survey of a fair sample of this total shows that on 12 per cent. one slide only was counted (these were usually found negative on first slide and the specimen examined later by Willis floatation), on 78 per cent. two slides, on 9 per cent. three slides, and on 1 per cent. four or more slides, or an average of 2 slides per tube. When two or more slides were counted from a tube, two or more microscopists examined them.

It was of interest to gather some information on the amount of time which the routine use of the small drop-displacement technic required. These "time studies" were made about the middle of our summer's laboratory work, under tropical conditions. Often the microscopists involved were not aware that their results were being recorded on a time basis.

There are two phases of the dilution method of examining fecal specimens, which are appropriately considered separately. The first comprises the tubing of the specimens, their preliminary shaking, and the recording of data as to case number, name, consistency of stool, etc., in the laboratory books. This was usually performed in the latter part of the afternoon. The second comprises such additional shaking of the tubes next day as is needful for thorough comminution of the contained feces, and the subsequent examination of the slides

with the aid of the microscope. As frequently emphasized, the drops for counting are eventually drawn following such mixing in the flasks by shaking as is required to produce an even egg suspension in the dilution tube.

For the complete job of tubing, the total time elapsing during the process on four typical occasions showed 76 specimens handled in 293 minutes (figured in terms of one man's time), or at the rate of 3.9 minutes per specimen. The usual procedure was first to fill the available clean flasks to approximately the 56 c.c. mark with decinormal sodium hydroxide from a bottle; then with an ordinary medicine dropper adjust the level of the diluent *exactly* to the 56 c.c. level by removing or adding small amounts of diluent; following this the individual tube was marked with the case number of the specimen using a soft wax pencil, the fecal sample was classified as to consistency and recorded, and the feces then introduced into the flask until the level of the contained fluid reached the 60 c.c. level *accurately;* to the tubes were then added glass beads, and No. 4 rubber stoppers, and a preliminary shaking given. Actual timing of these individual operations on about ten dozen tubes showed that on the average it required 0.8 min. to prepare a tube with diluent to the exact 56 c.c. level, 2.0 min. to displace the specimen accurately in the tube, and 1.1 min. per specimen for marking, classifying and recording.

The operation of tubing specimens for the displacement dilution technic including the specified items involved was thus at the rate of about 15 per hour per person engaged. It was found economical of time, as a matter of fact, to have two people work together, one preparing tubes with diluent, and recording case numbers, etc., in the laboratory record, the other doing the actual tubing of the specimen.

With the dilution flasks prepared in the afternoons, the mornings were given over almost exclusively to counting, this continuing into the day until all samples tubed the preceding day were completed. The amount of time required to perform the counting operation per slide was, therefore, secured in terms of the total amount of time spent in the laboratory in relation to the total number of slides counted. Results so computed thus include the time consumed in any incidental phases of the laboratory work, the usual interruptions to which a microscopist is subjected, etc. This is necessary if a laboratory worker's typical slide counting productivity is to be guaged. It may be mentioned, incidentally, that the fecal specimens examined had a relatively high incidence of ova of the three common parasitic nematodes. A fair sample of 1,019 specimens taken at random showed

84 per cent. contained the eggs of hookworms, 54 per cent. of ascaris, and 63 per cent. of trichuris. The egg counts were correspondingly high. (These of course are not to be taken as Panama incidence figures for these parasites. The data from that standpoint are analyzed in other sections of this report, as are the sizes of the egg counts.)

TABLE 1.

Analysis of small drop dilution slide counting proficiency by microscopists, Panama, 1926.

Microscopist.	Month.	No. of half-days studied.	Total hours timed.	Slides counted during period.	Av. no. slides counted per hr.	Equivalent minutes per slide.
T.....	July	5	14.7	44	3.0	20.0
U.....	July	5	16.3	63	3.9	15.4
	Aug.	5	15.7	61	3.9	15.4
V.....	July	10	33.3	156	4.7	12.8
	Aug.	10	32.9	202	6.1	9.8
W.....	July	6	18.3	60	3.3	18.2
	Aug.	6	19.5	99	5.1	11.8
X.....	July	3	8.5	35	4.1	14.6
	Aug.	3	10.5	52	5.0	12.0
Y.....	July	8	20.4	99	4.9	12.2
	Aug.	8	21.5	111	5.2	11.5
Z.....	July	6	16.2	80	4.9	12.2
	Aug.	5	10.0	51	5.1	11.8

In Table 1 are gathered the data for several microscopists covering a total of 80 "half-days studied," arranged to show July and August results separately. For July the average number of slides counted per hour ranged from 3.0 to 4.9, for August from 3.9 to 6.1. There is evidence of increasing efficiency for most of the workers. It should be mentioned that the experience of the microscopists in relation to the technic differed. Thus "T" was in his first month with the technic, "V" and "W" in their second and third months respectively; "T" and "W" had been familiar with microscopic work for several months, "V" only for a few weeks; the other workers listed in Table 1 were accomplished microscopists and had had considerable experience with the dilution method of egg counting.

These figures quite clearly indicate that under routine conditions, workers with reasonable training may be expected to examine small drop egg count slides at the rate of 4 to 6 an hour, based on the total time they spend in the laboratory on this phase of the technic.*

In order to determine somewhat more strictly just how such data compared with the time actually spent examining the slides, record was made for a number of individual slide counts with six of these same workers. Typical slides and counting conditions prevailed. In Table 2 are shown the results. (Hausheer, Herrick and Pearse, 1926,

TABLE 2.

Net time required for counting small drop dilution slides.

Micros-copist.	No. of slides timed.	Av. net time (minutes) per slide counted ($= x$).	Coefficient of variation.	Min. per slide from Table 1 ($= y$).	$\frac{x}{y}$ as per cent.
T.....	8	14.9 ± 1.7	47.3 ± 9.6 per cent.	20.0	75
U.....	22	11.6 ± 0.3	18.6 ± 2.0 per cent.	15.4	75
V.....	29	8.7 ± 0.2	20.6 ± 1.9 per cent.	11.3	77
W.....	22	12.1 ± 0.5	27.2 ± 3.0 per cent.	15.0	81
Y.....	29	8.1 ± 0.3	32.6 ± 3.2 per cent.	11.9	68
Z.....	13	9.2 ± 0.1	2.4 ± 0.3 per cent.	12.0	77

report counting time per slide as 11.0 ± 1.6 minutes.) As our figures were gathered about the end of July, they are compared with the information from Table 1, by expressing the "net time" per slide of Table 2, as a percentage of the "gross" average (mean of July plus August results) time per slide in Table 1. This shows that for the conditions prevailing in our laboratory, from 68 to 81 per cent. of the time indicated in Table 1 as the gross laboratory time required to examine small drop dilution slides, was actually spent over the microscope looking for ova.

* Taken in combination with the data given a few paragraphs earlier, workers of training equivalent to those here involved, may be thus expected to classify, tube, record, and dilution count specimens (average of about two small drop slides per tube) at the rate of 12.4 to 17.5 specimens per seven hour day, or two technicians together from 25 to 35 specimens daily. On the basis of the comparative Willis time studies (vide infra) which were also made, Willis floatations would be performed at the rate of 38 per person per same length day. In considering these figures, it is to be recalled that not only were the egg counts heavy (see later sections) but every slide was counted not only for hookworm ova, but for ascaris and trichuris as well. In the case of the Willis floatation they were primarily on hookworm egg count negative specimens and the whole Willis slide preparation was usually examined in order to secure information as to the presence or absence of hookworm, ascaris and trichuris.

Of the microscopists indicated in Tables 1 and 2, the two designated V and W were giving their full time to fecal examinations. It may be noted from Table 1 that for the occasions in July and August during which their actual records were analyzed, they averaged respectively about 5.4 and 4.2 dilution slide counts per hour. For six hours of microscopic work their efficiency would thus be 32.4 and 25.2 slides per day. It was of interest to summarize about two whole month's laboratory record of these men to compare with these figures. The period considered began after each had had about one month's practice with the methods and had for some time been doing acceptable work as to accuracy. In 8 weeks beginning July 13th V examined 1,489 slides and W 1,262, at the rate of 186 and 159 per week respectively or 31.0 and 26.4 per day. This computation does not make any distinction between Willis and egg count slides. If the days upon which each technician performed only the dilution technic are considered, their daily slide examinations were respectively 30.8 and 24.7. The output of counted slides figured for nearly half the summer's work thus corresponds well with the sample counts summarized in Tables 1 and 2.

From this analysis it would appear that an administrator could plan to have two reasonably efficient technicians handle the tubing and counting of about two slides per tube, of 30 specimens per day. Inasmuch as infestation rates were probably heavier than the ordinary in Panama, the above should represent only a reasonable minimum rate for a seven hour day. This moreover presupposes that not only hookworm ova, but those of other parasites are not only diagnosed but enumerated.

C. Tests of Willis technic.

Inasmuch as the Willis floatation had been the accepted critical technic for hookworm diagnosis in the regular Panama hookworm campaign, and inasmuch further as Hausheer, Herrick and Pearse (l. c.) had recently demonstrated its high efficacy under careful experimental conditions, it was used in our studies as a test for diagnosis on specimens negative to dilution count by small drop (Stoll and Hausheer, l. c.). It was possible also by doing Willis examinations on such of the dilution positives as opportunity afforded, to secure a measure of its efficiency in routine use under conditions in our laboratory. Furthermore the analysis furnishes some light of the comparative value of the Willis in revealing ascaris and trichuris infections.

The Willis examinations were performed chiefly by one technician, who had had some familiarity with the method previously and who

was given additional training with it. Special emphasis was placed upon thorough comminution of the feces, the use of saturated salt solution, and clean slides. The usual one-half ounce fecal sample tins were used and large slides. The amount of feces employed varied, depending sometimes upon the amount remaining after the dilution tube had been made from the same sample, but was always considered ample and in general approximated 1–2 grams.

The routine of handling specimens in the laboratory brought it about that they were tubed for counting on the afternoon of the day they were received, were dilution counted the next morning, and on that afternoon such specimens as had appeared negative to dilution count as well as certain additional ones were examined by the Willis technic. These examinations were made by the technician without knowledge of the dilution results on the same specimens. Inasmuch as the sample tins were kept in the refrigerator there was no development of ova in the interim.

Of about 3,500 specimens that were egg counted during the summer, 648 were examined by the Willis for hookworm ova, and of the latter 477 were also examined for ascaris and trichuris. It was our aim to have the Willis examinations such as an efficient diagnostic unit would perform under steady pressure of work and with reasonable supervision. This would naturally fail to give quite the perfection of technic achieved in so careful a study as that of Hausheer, Herrick and Pearse (l. c.), but would be somewhat more apt to reflect the situation in a regular diagnostic laboratory.

There were 492 dilution negatives for hookworm, of which the Willis method detected 104 or 21.1 per cent. positive. A striking difference was apparent, however, as to whether one or more than one dilution slide had been examined. As Table 3 indicates, of 396 samples

TABLE 3.

Summary of Willis floatation results on fecal specimens negative to small drop dilution slides.

Ova considered.	One dilution slide negative.			More than one dilution slide negative.		
	Total ex.	Willis positives.		Total ex.	Willis positives.	
		Number.	Per cent.		Number.	Per cent.
Necator	396	94	23.7	96	10	10.4
Ascaris	212	4	1.9	74	3	4.1
Trichuris	241	35	14.5	72	12	16.7

negative to one dilution slide, 94 or 23.7 per cent. were positive by Willis; of 96 negative to more than one dilution slide (for 77 two dilution slides were examined, for the balance three), 10 or 10.4 per cent. were positive by floatation. This accords with the theoretical demands, for one small-drop dilution slide should not detect infections of less than 200 eggs per gram in the feces examined (one egg present on a small drop slide representing a count of 200 to the gram or c.c.), whereas two would reach down to the 100 egg per gram group and would accordingly catch more of the positives, leaving a smaller percentage for the Willis to declare.

Inasmuch as it may be assumed that the fecal samples which the laboratory was examining contained a fair scatter of light hookworm positives among the dilution negatives (as indeed, the above figures prove), it was of interest to see whether there were differences in results depending on the consistency of the stool used. All specimens examined at Penonome were classified according to one of five consistencies as earlier noted. Hitherto no account seems to have been taken of the consistency of stools in relation to the diagnostic efficacy of egg finding methods.

TABLE 4.

Willis floatation results for hookworm on stools negative to one small drop dilution slide, classified as to consistency of feces.

	Formed.	Soft-formed.	Mushy.	M-D.	Diarrh.
Total no. examined	42	62	242	35	14
No. Willis positive	9	18	58	8	1
Per cent. positive	21.4	29.0	23.9	22.9	7.1

In Table 4 are shown the respective number and percentage of Willis hookworm positives on stools which had one small-drop dilution slide negative. Within the limits of the numbers of cases in the different categories, there is no clearly demonstrable difference exhibited. This is rather contrary to what might have been expected, for setting ova free from formed feces in the Willis technic is not apt to be so well accomplished as in the softer specimens where presumably the eggs are less tightly bound to the fecal debris. Two factors probably account for the fact that one type of stool furnishes approximately as reliable results as another. Thus, with any arbitrary worm burden a given sized mass of feces, for instance one or two c.c., contains a greater number of ova when firm than when soft, and as only one or a few need to be present on a Willis slide to furnish a positive diagnosis, a smaller percentage floatation from a given mass of firm

feces would in the long run balance a greater percentage floatation from the same sized softer quantity. So far as our results are typical, there is thus no comparative inefficiency for hookworm ova with the Willis technic in relation to stool consistency.

Re-examining Table 3 for Willis results with ascaris and trichuris shows a very low yield of positives with ascaris, but a better result with trichuris, no sound difference in percentage efficiency being revealed depending on whether one or two dilution slide negatives had been previously secured. The very low percents with ascaris are probably ascribable to two factors. One is the strikingly smaller efficiency of the Willis floatation with ascaris, than with either trichuris or hookworm (vide infra), the other that ascaris eggs when present, are usually numerous enough to be readily caught by egg count. Brown and Cort (1927) have noted that ascaris females lay above 200,000 eggs per day. The period, therefore, in any ascaris infection when the eggs would be less numerous than 200 per gram, i.e., the minimum figure that the small drop dilution slide should ordinarily detect, would be more transient than with hookworm or trichuris, No differences could be noted in our data as to any influence of stool consistency on the floatation results with ascaris and trichuris.

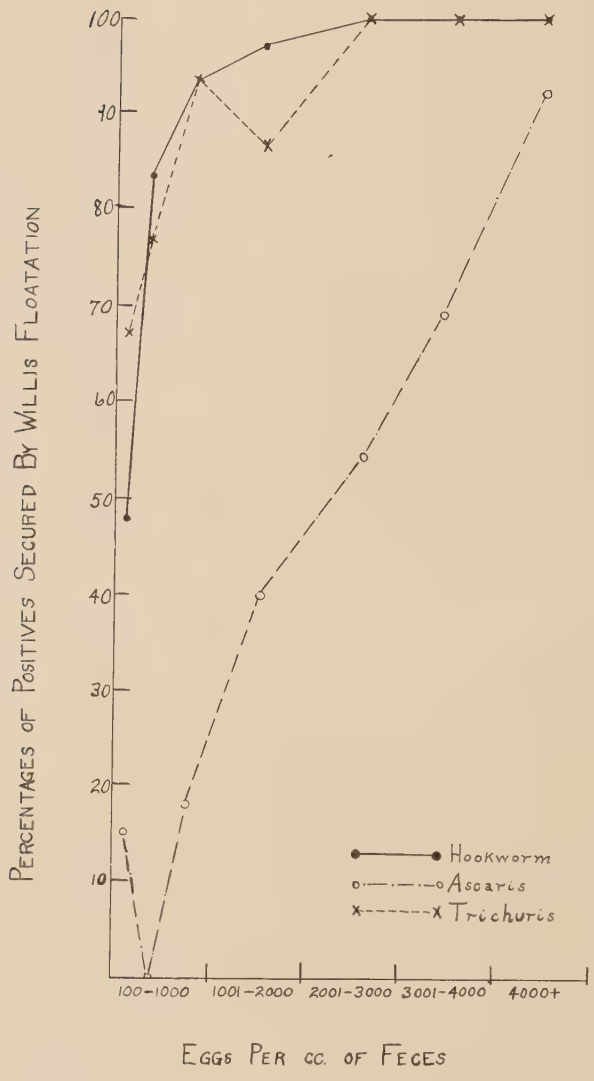
It was possible, by making Willis floatations of feces which had been shown positive by dilution count, to add direct information to the indirect given above, as to the comparative efficacy of this technic in the infections examined. Table 5 and Graph 1 illustrate the

TABLE 5.

Willis floatation results on dilution positives, Panama, 1926. See Graph 1.

Egg count per c.c. of stool.*	Hookworm, Willis floatation.			*Ascaris*, Willis floatation.			*Trichuris*, Willis floatation.		
	No. examined.	No. positive.	Per cent. positive.	No. examined.	No. positive.	Per cent. positive.	No. examined.	No. positive.	Per cent. positive.
Up to 200...	38	18	48	20	3	15	61	41	67
201–500....	12	10	83	6	0	0	40	31	77
501–1,000...	14	13	93	17	3	18	28	26	93
1,001–2,000.	36	35	97	20	8	40	22	19	86
2,001–3,000.	15	15	100	13	7	54	5	5	100
3,001–4,000.	14	14	100	16	11	69	3	3	100
Over 4,000..	27	27	100	96	88	92	5	5	100
Total.....	156			188			164		

* As counted, without regard to consistency.



GRAPH I. Percentages of positives secured by Willis floatations at different egg count levels for hookworm, ascaris and trichuris. See Table 5 and text.

results. In the case of the eggs of each parasite, an increasing effectiveness is shown by the Willis technic, as the number of eggs present increases. With both hookworm and trichuris the efficiency rapidly rises until the 2,000 eggs per c.c. level beyond which all cases were caught by floatation. The ascaris curve, however, starts distinctly

lower and rises more slowly, so that at the 2,000 egg per gram level less than half the positives are demonstrated by the Willis, and there is still occasional loss of positives at double that grade of infection. Using F, SF and M to indicate stool consistency, the eight Willis negatives above 4,000 eggs per c.c. showed respectively F 4,200, M 5,300, M 5,900, M 7,500, SF 8,600, M 9,200, M 9,300 and SF 24,600 ova. It seems difficult to believe that such sized infections could be missed except by carelessness of the technician, but the fact that the curve does not change radically throughout its course indicates that more fundamental reasons are possibly involved. (A reexamination of the original record indicates that all the dilution positive hookworm and trichuris infections were spotted in these eight stools by the Willis technic, and two dilution negatives for hookworm were changed to positive by the floatation.)

It seems to us that the poor results with Willis floatations of ascaris are not only related to the fact that these eggs are probably more adherent to the fecal debris through the fact of their rough "albuminoid" cover, but that due to their size they are retained with more difficulty in the thin upper layer of the salt solution which is brought off when the Willis slide is lifted from the container to be inverted and placed on the microscope stage. It is possible too that they are inherently more difficult to float in saturated salt than either hookworm or trichuris. Certainly in view of these findings too much reliance cannot be placed on the results of Willis examinations for ascaris. The incidence figures with dilution counts alone on ascaris appear to be much more reliable. On the other hand, as much confidence may apparently be placed on Willis examinations for trichuris as for hookworm, although as a routine procedure it misses about one case in five of infections showing 500 or less eggs per gram by dilution count, according to our data.

In specimens which were dilution negatives but Willis positives the egg count was arbitrarily figured as 100 eggs per c.c. of stool.

The time taken for completing the entire Willis examination was totaled for 256 specimens. It was at the rate of 11.1 minutes per fecal sample. This is presumably somewhat higher than would be true had our laboratory unit been doing only Willis examinations. On the other hand it would appear to be a fair estimate of the time under conditions where this floatation method is merely used to check the dilution negatives.

D. Summary.

The routine handling of the dilution egg counting and Willis floatation technics as applied to hookworm, ascaris and trichuris ova are described, and certain results as to the time required to handle them are noted. In addition a test is shown of the comparative lack of efficacy of diagnosing ascaris infections by the Willis technic, at the same time that hookworm and trichuris infections are diagnosed with a relatively high efficiency.

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III. STOOL SIZE AND ITS RELATION TO EGGS IN THE FECES.

By

N. R. STOLL.

The most reliable measure of hookworm burden by the indirect method of estimating it with the egg count, is secured by the total egg output per day from infested cases. As shown by Stoll (1924) in the examination of egg outputs for 15 and 40 day intervals, this eggs per day figure is a fairly level one, especially when three or more days enter the average, so as to smooth out the irregularity of the fecal bulk itself. Brown (1928) has recently reviewed these data, and added additional series of the same import with hookworm, ascaris and trichuris. Similar results have been secured in the study of infected animals, by Faust and Khaw (1927) with *Clonorchis sinensis* in cats, guinea pigs and dogs, and by Herrick (1928) with *A. caninum* in dogs.

The usual use of egg count data in routine examination or survey work does not permit the gathering of information in those terms, however, so that reliance is placed on eggs per gram or c.c. of original stool instead. Certain variables enter here which do not appear in total egg output data. These have to do with consistency of the stool, total amount of fecal output per day, and different sized stools due to age. During the Panama studies an effort was made to gather data with special reference to age. Their analysis permits emphasis on the first two factors as well.

In gathering fecal output data for such studies as these, it is important to secure them under as nearly natural conditions as possible. Thus information from hospitalized patients may not reflect typical conditions in a population from which the patients come, for hospitalized patients are much more apt to be better fed. Accordingly the scattered villagers in the community of Marica Arriba, near Penonome, were requested to furnish complete stools in paraffined cardboard boxes of pint size (oyster containers). The field inspector visited each household, and where possible each individual of the household, writing for each person the name, age, sex, and hour of last previous defecation on the box. These boxes were then left with

instructions to deposit the whole of the next stool therein, together with noting its time. On the next day a return visit was made by the inspector, the hour of the presented defecation written upon the container, and the specimens transported to the laboratory. By making a sufficient number of return visits the field worker was eventually able to secure full stool specimens from 96 individuals, all but 5 of which were accompanied by the requisite information.

At the laboratory these specimens were classified as to consistency and weighed. Of the 91 specimens 30 were formed, 25 soft formed, 35 mushy and 1 diarrheic. The latter was excluded from further consideration. Certain additional preliminary information on the net total of 90 may be given before analyzing the stool weights. The contributors were 43 males ranging in age from 3 months to 84 years, and 47 females from 3 months to 55 years. Of the total age distribution 27 were under ten years, 19 from 10 to 19, and 44 twenty years and over. The time intervals between the stools collected and the last previously reported ranged from 5 hours (by a man of 40 years) to 119 hours (by a woman of 47), the means for all being 27.4 ± 1.2 hours, with a standard deviation of 16.2 ± 0.8 hours. When the intervals between stools are grouped according to the consistency of the feces, there was no valid difference shown, although it is possible a larger series might have borne out the possible fact that more hours elapse before the passage of formed specimens, than before soft formed or mushy. Thus, the data showed that 30 formed stools were passed after an average interval since the preceding defecation of 32.7 ± 2.5 hours (range 10 to 119 hours); 25 soft formed stools after an average interval of 25.4 ± 1.4 hours (range 7 to 50); and 35 mushy stools after an average interval of 24.7 ± 1.5 (range 5 to 59). The widest gap here, between the formed and mushy intervals, at 8.0 ± 2.9 hours, is not clearly other than a chance difference. A difference in interval is apparent, however, between children and adults. Without regard to consistency of stool (which as in the total series shows no contrasts), the 39 children through age 14 show a mean interval between stools of 22.1 ± 1.5 hours, whereas 51 individuals age 15 and over have a mean of 31.4 ± 1.6 hours, an evidently valid difference of 9.3 ± 2.2 hours. It is rather puzzling to know the meaning of this, unless with juveniles generally the "call of nature" is responded to promptly at the summons, instead of being postponed. The fact that our data are derived from specimens which were requested in given containers might have meant that some of the adults, presumably the males, kept themselves under some restraint in order to

utilize the containers at a convenient hour. If such were the case a difference between the adult males and females might be apparent as between workers in the field and in the household. However, of those 15 years of age and over, 28 males show an interval of 30.0 ± 1.5 hours, and 23 females 33.1 ± 3.0 hours, a difference due to chance clearly.

The method of analyzing the data from these individuals in terms of amount passed per day, has been to divide the weight of the submitted stool by the number of hours elapsed since the previous bowel movement, thereby securing the average weight of feces passed per hour, and multiply this by 24 to secure the per diem output.

Stool size and consistency.—In an earlier article (Stoll, 1923) the writer called attention to the difference in amount of stool passed per day per person, depending on its consistency and the fact that formed feces per day represented only half the number of grams of mushy feces. Hill (1926), also working in Porto Rico showed further that there is an allowable classification between formed and mushy, which he designates "soft formed." His figures of the mean weights of stool passed per day in the formed, soft formed and mushy groups show the ratio 1.00 : 1.54 : 2.14.

In the Marica Arriba series, of 51 adults (ages 15 and over), 19 passed formed specimens with a mean weight of 86.3 ± 7.8 grams per day, 12 passed soft formed feces with a mean weight of 126.2 ± 13.1 * grams and 20 passed mushy specimens with a mean weight of 169.8 ± 25.6 gram. The mean weights here of soft formed outputs are not significantly different from those of formed on the one hand or mushy on the other, a condition rising from the limited series. The three types differ in size in the usual fashion, however, having the ratio 1.00 : 1.46 : 1.97, closely approximating Hill's data in this respect. The result permits the interpolation of figures from all cases to be brought to the basis of formed feces for the further analysis. Furthermore they represent locally gathered evidence in favor of the usual procedure of putting egg counts on a basis of formed feces for the Panama studies.

Amounts of feces, basis formed, passed per day.—It was pointed out by Cort, Stoll and Grant (1926) that in making comparisons between different communities, especially those in different countries (as, for instance, Porto Rico and China), average egg counts on a formed feces basis need to take into account the average size of formed

* In figuring probable errors where the number of cases is less than 15, the n consulted in Pearson's Table V has been one less than the actual n.

stools per day in the communities compared. Thus, while the average formed feces output per day observed in Porto Rico is about 150 grams, in China it is closer to 100 grams. China egg counts, basis formed feces, would thus need to be read in terms of 2/3 their average amount per gram in comparing them with Porto Rico counts, basis formed feces, or the latter would need to be read in terms of 3/2 their average amount per gram in comparing with the China counts. The reasons for this are obvious.

By using the results of the 51 adult cases from Marica Arriba (ages 15 and over) as a single group, the mean formed feces output per day becomes 85.2 ± 6.1 grams. While the coefficient of variation of the series is high at 76.0 ± 7.4 per cent. it is probably not excessively so for this type of data. For instance there appear to be four cases in the literature, each studied for several days, in which formed stools only were passed, two each reported by Brown (l. c.) and Soper (1926). Brown's Case I, a girl of 8, over 11 days showed a C.V. of 15.0 ± 2.3 per cent., but his Case II, male 23, over 23 days showed a C.V. of 90.0 ± 14.5 per cent.; Soper's Case B, male 35, over 10 days showed a C.V. of 85.3 ± 25.5 per cent., and his Case B_1 (same individual a month later, using period September 5–20 inc.) over 15 days a C.V. of 168.5 ± 53.7 per cent.

To the extent to which our field data were accurately gathered in this fecal output study, and we believe the errors to be at a minimum, the average formed feces output per day of the Panama natives is demonstrably small. It does seem to us possible that a psychological factor may have decreased the total size of the specimens somewhat, namely the requirement of collecting specimens in pint size containers from people accustomed only to natural conditions. This may have caused the passage of somewhat smaller stools than is usually their rule. While we have no mensurable data bearing on the point, we are inclined, considering its potential influence, to consider the average formed fecal output of adult natives such as those of Marica Arriba, as approximating 100 grams per day (vide infra data on ages 5 and over). The population under study, therefore, represents a direct comparison on this score with the natives studied in China rather than with those of Porto Rico, where the average formed fecal output per day by adults is about 150 grams. This concentration of stools of the Panamans, causing as it does concentration of ova in the stool, is to be kept in mind in judging the size of egg counts secured from them.

It would be valuable to have more information of this sort as a

basis for directly comparing average egg counts in different parts of the world. Thus Chandler (1928) in his recent studies in India, has used mushy feces for his basic figure of average egg counts. The degree to which his results are directly comparable to average egg counts elsewhere in the world is compromised by a lack of information as to just what the average adult mushy fecal output in India is in grams per day.

TABLE 1.

Stool weights per 24 hours, basis formed feces, of a village group of 90 persons (Marica Arriba) in Panama, July 1926.

Age group.	No. of cases.	Mean grams ± P.E.	Coefficient of variation.
1–2	6	23.0 ± 4.7	67 per cent.
3–4	12	46.9 ± 5.3	56 per cent.
5–9	9	75.1 ± 15.7	88 per cent.
10–14	12	151.1 ± 35.9	117 per cent.
15–19	7	82.6 ± 13.3	59 per cent.
20–39	29	75.5 ± 5.0	53 per cent.
40 and over	15	105.2 ± 16.9	92 per cent.
Total 5 and over	72	94.9 ± 5.9	78 per cent.
Total 15 and over	51	85.2 ± 6.1	76 per cent.

Probable errors for groups of less than 15 figured on a basis of $n - 1$.

Amount of feces, basis formed, in relation to age.—The data bearing on this point are given in Table 1. Due to the small numbers of cases in most of the age groups the variability in the amounts of formed feces per day according to age is high, as shown by both the large probable errors, and the coefficients of variations. Certain items are worth stressing, however. Dealing with the mean values only, ages 1–2 show 23.9 ± 7.1 grams less of formed feces than ages 2–3, clearly a valid difference as would be expected. The difference between ages 3–4 and 5–9, at 28.2 ± 16.6 grams is here not other than might have occurred through chance alone. Beginning at age 5, however, none of the age groups specified show other than chance fluctuations. If thrown together as a single series of 72 cases the formed fecal output for all ages 5 years and above has a mean of 94.9 ± 5.9 grams, and a coefficient of variation of 78.3 ± 6.7 per cent., not sensibly different from the adult figures (51 cases, age 15 and over) given earlier of 85.2 ± 6.1 and 76.0 ± 7.4 per cent. When the mean output of ages 5 and over is compared to that of the 3–4 age group, there is clearly a

significant difference of 47.6 ± 7.9 grams. The figures for the 5–9 year group are much higher than anticipated, but there are too few cases to resolve it into small subgroups. It is probable that with the high ratio of the probable error to the mean in the 10–14 age group, that an unusual condition exits either in this group due to adolescence or in our data for some unknown reason. One might venture to predict that a larger series would show an adult average approached close to age ten, with values below age ten representing some fairly constant smaller rate for each year of decreasing age.

So far as our figures go, however, they permit clearly, a statement that fecal output in the 3–4 age group is only half that of the adults, and in the 1–2 year group only about a quarter. Egg counts then in these groups need to be corrected in accordance with these conclusions in comparing with adult counts. Thus of three 10,000 eggs per gram counts, basis formed, from respectively a two year old, four year old, and adult, the comparable counts would be represented by 2,500, 5,000, and 10,000 eggs per gram.

The recent paper by Brown (l. c.) gives certain data which bear on the above findings. He gives the gram outputs of four cases in Panama studied several days each. Reduced to formed feces per day, his Case I, female 8, over 11 days had a mean output of 93.6 grams; Case III, male 8, over 10 days, a mean output of 66.0 grams; Case IV, female 5, over 15 days, a mean output of 98.1 grams; these three cases of the age group 5–9 thus average about 86 grams formed feces per day. Brown's Case II, male 23, over 23 days, had a mean formed feces output of 69.0 grams.

Little attention appears to have been paid hitherto, to the effect of small stools of children in the analysis of egg counts. In an article by Docherty (1926) there is a footnote that "children have smaller stools than adults, which would give higher egg counts than adults with similar worm burdens." Chandler (1928) tacitly acknowledges that a correction should be involved for children's stools "but since there is good evidence that a given degree of infection is more harmful in children than in adults, . . . a statement of the number of eggs per gram gives a fair rough indication of the severity of the infection as compared to adults." Smillie and Augustine (1926) studying school children in Alabama for the effects of hookworm intensities, appear not to have allowed for differences in total fecal output in different ages. It is thus possible that their estimate of the innocuous worm burden for children may be spuriously somewhat high.

Whatever correction may be required to bring the individual egg

counts on children to a level where they may be directly compared to those from adults, it is to be emphasized that the use of an average egg count with such a standard population as is described in the next section of this report, automatically gives the proper mathematical emphasis to children's counts.

Besides its effect on the size of egg counts it is worth noting that the smaller stools of children modify the level of efficacy of any diagnostic method as well. Thus a technic, such as the smear, which is shown by Cort, Stoll and Grant (l. c.) and Hausheer and Herrick (1926) to detect infections of 400 to 500 eggs per gram or more with regularity, will pick up lighter worm burdens in children with their smaller stools, than with adults, for 500 eggs per gram among the children means fewer worms in the host than in an adult. Unless there are chemical characteristics in certain juvenile stools which cause a technic to function less perfectly than with adult feces (as, for instance, the recognized inefficiency of floatation with salt on milk stools), it may be accepted that incidence data on smaller children are much more accurate than on adults examined by the same method This conclusion includes the assumption that a given number of hookworms produces in children the same egg output per day which a similar number of hookworms would produce in adult hosts.

In conclusion it may be stated that while the new data here presented are from only 90 cases, when 900 cases would have been preferable, the distinctions made appear to be indicative of fundamental trends. It would be valuable to have more information of the type collected and analyzed in other areas in the world.

Summary.

1. The ratio of about $1 : 1\frac{1}{2} : 2$ for the weights of formed, soft formed and mushy stools passed per day holds for the Panama group studied as Hill (l. c.) earlier demonstrated for Porto Rico.

2. The average amount of feces, basis formed, passed by the Panama native studied approximates 100 grams per day, a figure comparable to the Chinese average reported for China by Cort, Stoll and Grant (l. c.) but less than the Porto Rico standard of 150 grams reported by Stoll (1923) and Hill (l. c.). This is to be taken into account in comparing egg counts from these areas.

3. In one village studied, considered typical of Panama conditions, children of 1–2 passed only about one fourth, and children of 3–4 about one half as much formed feces per day as adults, and that ages 5–14 show averages not statistically distinct from the adults.

4. In view of the smaller sizes of children's stools, compared to adults, and of adult stools in different countries, more data of this kind are necessary to clearly define such differences.

5. The smaller size of children's stools not only modify the interpretation of egg count data, compared to adults, but incidence data by any technic as well.

6. A general statement of a community egg count average, based on a standard population, automatically corrects for the size of children's stools and the consequent concentration of eggs therein.

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IV. THE CORRECTION OF HOOKWORM RATES FOR AGE AND SEX.

By

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Reports on work done in the control of hookworm infection in various parts of the world have made use of two methods of estimating accomplishments. In the earlier work all reports, except when actual counts of worms were made, dealt in qualitative figures, percentages of any population group infected with hookworms. With the introduction of methods for estimating the *degree* of such infections, there has been a more or less complete adoption of some quantitative method for the report of hookworm studies.

Both the qualitative and the quantitative reports are open to objection, when used in comparing the hookworm situation in one group or country to that in another, in that they take no account of the relative age and sex make-up of the two groups. Within any particular group of people, the age distribution is one of the most influential elements in determining any conclusions; to a lesser extent this is true of the proportionate sex make-up of groups. The comparison of reported averages of infection with hookworms, obtained by either method, is at present impossible without serious error due to the variations in age and sex make-up of the many groups examined.

In the first paper of the report of the China Hookworm Commission, Cort, Stoll and Grant (1926) say:

"A final and proper statement of the degree of human infestation with hookworms in China, or elsewhere, whether by use of egg count or any other method of expressing it, should not fail to take into account these age distributions." In following out this principle they used what they considered a fair estimate of the age distribution of the Chinese population and so weighted their results that they obtained some general correction of all their reported group averages for this standard age make-up of the whole population. They tabulate several Chinese age distributions in comparison with that of the U. S. A., 1910 census.

Such a method is a step in the right direction but would be applicable to various groups of people from one country only. Each

survey would weight its average egg counts in terms of the age distribution of the population of the particular country in which it was made but the results of the weighting would not allow comparison with average counts obtained in other countries. What is needed, then, is some standard population which can be used for all groups in such a way that corrected average egg counts can be compared with similar averages obtained elsewhere without question as to the validity of the comparisons on the grounds of differing age and sex distributions.

The use of corrected death rates by many of the census bureaus of the world points to a method for correcting egg counts. In corrected death rates the specific death rates for age groups of the local population are applied to some standard population and a resulting rate obtained which is corrected for age and can be corrected for sex. Since most of the hookworm infestation of the world is in tropical or subtropical countries and most of the surveys will be reported from such countries, it would seem advisable to adopt the population of a tropical country as a standard so that the distribution to be used may differ as little as possible from that actually found in the countries which will make the most use of the method. Most tropical countries have no adequate census returns from which to make up a standard population but search through the records shows that the population of Porto Rico in 1910 (as recorded in the Thirteenth Census of the U. S.) was so published that it can be used to form almost any desired age groups. The age and sex distribution of the population of Porto Rico in 1910 is, therefore, suggested as a standard to be used in correcting hookworm rates.

The Porto Rican population of 1,117,958 persons in 1910 is given in Table 1 with the percentages of the total population forming each age and sex group. (Fifty-four persons, 21 males and 33 females, were omitted from this table as their ages were not stated in the census returns.) Single ages are given up to 24 years but above that age the usual five year groups of census reports are given. If this suggested standard is used, it will be necessary for future hookworm survey reports to make use of the accepted census age groupings, a change which would greatly facilitate the study of reported results. At present many different age groupings are in use and comparisons of reported results are difficult. The individual ages are included in this table to facilitate the forming of any desired combination but it is strongly urged that any combinations made be on such a basis that they can be amalgamated into the usual census groupings, 0–4, 5–9, 10–14, 15–19, 20–29, 30–39, etc.

TABLE 1.

Population of Porto Rico in 1910, from thirteenth census of the United States.

Age.	Males.		Females.		Both sexes.	
	Number.	Per cent. of all males.	Number.	Per cent. of all females.	Number.	Per cent. of total population.
Under 1	20,175	3.62	19,685	3.51	39,860	3.57
1	17,154	3.08	16,424	2.93	33,578	3.00
2	20,288	3.64	19,222	3.43	39,510	3.54
3	18,428	3.31	18,100	3.23	36,528	3.27
4	18,168	3.26	17,545	3.13	35,713	3.19
0–4	94,213	16.91	90,976	16.23	185,189	16.57
5	16,824	3.02	15,898	2.83	32,722	2.93
6	15,710	2.82	15,454	2.76	31,164	2.79
7	16,999	3.05	16,955	3.02	33,954	3.04
8	16,370	2.94	15,541	2.77	31,911	2.85
9	10,669	1.91	10,803	1.93	21,472	1.92
5–9	76,572	13.74	74,651	13.31	151,223	13.53
10	17,217	3.09	16,078	2.87	33,295	2.98
11	11,708	2.10	11,183	2.00	22,891	2.05
12	19,261	3.46	17,284	3.08	36,545	3.27
13	11,640	2.09	11,347	2.02	22,987	2.05
14	14,454	2.59	13,579	2.42	28,033	2.51
10–14	74,280	13.33	69,471	12.39	143,751	12.86
15	12,950	2.32	13,909	2.48	26,859	2.40
16	11,020	1.98	12,334	2.20	23,354	2.09
17	7,578	1.36	9,202	1.64	16,780	1.50
18	13,628	2.45	15,045	2.68	28,673	2.57
19	8,212	1.47	9,911	1.77	18,123	1.62
15–19	53,388	9.58	60,401	10.77	113,789	10.18
20	11,830	2.12	16,340	2.91	28,170	2.52
21	9,523	1.71	7,043	1.26	16,566	1.48
22	12,734	2.29	12,241	2.18	24,975	2.23
23	10,163	1.82	9,268	1.65	19,431	1.74
24	9,242	1.66	10,124	1.81	19,366	1.74

TABLE 1 (*Continued*).

Age.	Males.		Females.		Both sexes.	
	Number.	Per cent. of all males.	Number.	Per cent. of all females.	Number.	Per cent. of total population.
20–24	53,492	9.60	55,016	9.81	108,508	9.71
25–29	45,836	8.22	48,377	8.63	94,213	8.42
30–34	35,331	6.34	35,091	6.26	70,422	6.30
35–39	32,283	5.79	32,005	5.71	64,288	5.75
40–44	26,539	4.76	25,805	4.60	52,344	4.68
45–49	18,977	3.41	18,186	3.24	37,163	3.32
50–54	16,867	3.03	16,484	2.94	33,351	2.98
55–59	9,241	1.66	9,552	1.71	18,793	1.68
60–64	8,996	1.61	10,137	1.81	19,133	1.71
65–69	4,612	0.83	5,211	0.93	9,823	0.88
70–74	3,156	0.57	4,250	0.76	7,406	0.66
75–79	1,525	0.27	1,920	0.34	3,445	0.31
80–84	1,139	0.20	1,752	0.31	2,891	0.26
85–89	472	0.08	669	0.12	1,141	0.10
90–94	224	0.04	448	0.08	672	0.06
95 and over	137	0.03	276	0.05	413	0.04
50 and over	46,369	8.32	50,699	9.05	97,068	8.68
60 and over	20,261	3.63	24,663	4.40	44,924	4.02
70 and over	6,653	1.19	9,315	1.66	15,968	1.43
80 and over	1,972	0.35	3,145	0.56	5,117	0.46
All ages	557,280	100.00	560,678	100.00	1,117,958	100.00
Ratio males and females	557,280	49.85	560,678	50.15	1,117,958	100.00

TABLE 2.

Contrast by ten year groups of the age distribution in a tropical (Porto Rico, 1910) and a temperate zone population (U. S. A., 1910).

Age group.	Per cent. Porto Rico, 1910.	Per cent. U. S. A., 1910.
0–9	30.09	22.2
10–19	23.04	19.8
20–29	18.13	18.7
30–39	12.05	14.6
40–49	8.00	10.6
50–59	4.65	7.2
60 and over	4.01	6.6
Total	99.97	99.7

TABLE 3.

Egg counts reported for patients in Soochow hospital as corrected for age and sex. The general average for this group, corrected for both age and sex, becomes 730 E.p.g.

Age.	Males.			Females.		
	A. Actual E.p.g. "basis formed."	*B.* Per cent. at ages in standard population.	*C.* Correction for egg counts (*A* x *B*).	*D.* Actual E.p.g. "basis formed."	*E.* Per cent. at ages in standard population.	*F.* Correction for egg counts (*D* x *E*).
0–9	125	30.65	3,831.25	338	29.54	9,984.50
10–19	776	22.91	17,778.16	216	23.16	5,002.56
20–29	2,191	17.82	39,043.62	886	18.44	16,337.84
30–39	1,282	12.13	15,550.66	276	11.97	3,303.72
40–49	1,229	8.17	10,040.93	133	7.84	1,042.72
50–59	45	4.69	211.05	3,990	4.65	18,553.50
60 and over	162	3.63	588.06	1,067	4.40	4,694.80
Totals	—	100.00	87,043.73	—	100.00	58,919.64
Averages	1,362	—	870	652	—	589

That this suggested Porto Rican standard of a tropical population differs in certain significant particulars from a temperate zone population is illustrated in Table 2, where it is placed in contrast to the age distribution of the whole United States (1910) as given in Cort, Stoll and Grant (l. c.). In the ages under 20 the tropical group has over 53.0 per cent. of the whole population, while the United States proper shows only 42.0. The reverse contrast appears in the later ages, where only 16.7 per cent. of the Porto Ricans are 40 years of

age or older, while 24.4 per cent. of the whole United States population are in these older groupings. Moreover of the whole population, 49.9 per cent. of the Porto Ricans are males, while the percentage for the whole United States is 51.5.

The results of the Soochow Hospital inpatient survey of Stoll, Tseng and Li (1926) are used to illustrate the method of correcting for age and sex. The data are given in Table 3. The correction for age is applied by multiplying the average egg count (all figures "basis formed feces") for a given group, by the percentage of the standard population in that age and sex group, adding these products and dividing by the sum of the percentages (which sum, when all ages are included in the original census, will be 100). As the ratio of males to females in the standard population is almost equal (see bottom of Table 1), a final correction for the general egg count average for "both sexes" can be easily secured by taking the mean of the corrected male and female egg counts. When the average counts for males and females are not separately tabulated, the combined figures for "both sexes" in the different age groups can be corrected directly, illustrated for rates Table IV. For the Soochow Hospital group the general average of 1,362 eggs per gram of the males becomes, when corrected, 870; that for the females changes only slightly, from 652 to 589; while that for both sexes, given as 1,152, becomes 730 eggs per gram.

The same method of correction can be applied to the percentage incidence rates reported in hookworm literature, as shown in Table 4 where rates reported for Australia (Sweet, 1924), part of Siam (Barnes, 1921), and a survey of Porto Rico (Grant, 1920) are corrected for age; as no figures were given by which the incidence of hookworm in the two sexes might be determined by age, it was not possible to correct for sex. The Australian incidence rates are not changed to any extent by correction for age and only slight changes are made in the rates for Siam and Porto Rico. Enough of a change is made, however, to allow for the conclusion that, when the age grouping of the populations are made alike, Porto Rico had a slightly higher infection rate than Siam, rather than vice versa.

The use of corrected rates is open to error of various kinds and must be handled with some caution. The correction for age, however, is of such importance in hookworm rates, either quantitative or qualitative, that the suggestion that they be widely used seems justified. The authoritative figures in any particular instance are, or should be, the ones actually obtained and no corrected rates need be substituted for these in determining control work; the judicious

TABLE 4.

Typical hookworm incidence rates (= percentages infected), showing correction for age. All data are for both sexes combined.

A. Age groups.	*B.* Per cent. of standard population in these age groups.	Australia (Sweet).		Siam (Barnes).		Porto Rico (Grant).			
		C. Per cent. infected.	*D.* Correction for rates (*B* x *C*).	*E.* Per cent. infected.	*F.* Correction for rates (*B* x *E*).	*G.* Age groups.	*H.* Per cent. of standard population in these age groups.	*I.* Per cent. infected.	*J.* Correction for rates (*H* x *I*).
0– 5.....	19.50	10.9	212.55	51.8	1,010.10	1–10	33.08	76	2,514.08
6–18.....	32.02	22.3	714.05	83.0	2,657.66	11–20	22.58	78	1,761.24
19–39.....	31.80	10.4	330.72	83.0	2,639.40	21–39	27.66	84	2,323.44
40–59.....	12.66	6.2	78.49	82.9	1,049.51	40–59	12.66	85	1,076.10
60 and over.	4.02	2.6	10.45	79.8	320.80	60 and over	4.02	75	301.50
Totals.....	100.00	—	1,346.26	—	7,677.47	—	100.00	—	7,976.36
Averages...	—	13.7	13.5	81.1	76.8	—	—	80.8	79.8

application of a correction to rates, however, can be made to result in a greater degree of accuracy in conclusions when comparisons of district to district or country to country are desired.

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V. AN ANALYSIS OF HOOKWORM INFESTATION IN AREAS IN PANAMA UNINFLUENCED BY CONTROL MEASURES.

By

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Outline.

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A. Introduction.

The studies on the epidemiology of hookworm disease in the Republic of Panama carried out in the summer of 1926 involved the making of egg counts and soil pollution and soil infestation surveys for eleven different population groups. The purpose of the investigation was to obtain information on the hookworm situation in Panama under conditions as yet uninfluenced by treatment and sanitation and also to evaluate the effect of the control program as developed in Panama as judged from the conditions in places where work had been carried on. In this section we will consider only those groups of people included in our studies in which the degree of infestation appeared to be practically uninfluenced by any phase of the control campaign. From the Penonome district in Cocle Province the untreated individuals will be analyzed from the unsanitated villages of Chorrerita, El Coco and Cocle as representative of the rural communities of the whole coastal plain of the Pacific littoral. From the same district there are available the villages of Sardina and Marica Arriba, which are in the hills at the edge of the plain. As representative of the upland areas, we will include the village of La Soledad and the unsanitated part of the village of La Atalaya in the Santiago District of Veraguas Province, where the rainfall is considerably greater than in the coastal plains and the vegetation near the houses quite dense. The description of these places is given in some detail in Section I. Each of them will first be considered separately with relation to soil pollution, soil infestation and the degree of human infestation as measured by the dilution egg counting method. With this information before us the attempt will be made to analyze the factors which have operated in producing the level of hookworm infestation characteristic of Panama. The situation in this country as represented by the groups of people studied shows two striking characteristics of especial interest. In the first place the intensity of infestation demonstrated by our egg counts is very high when compared with that reported from other places in the world from which similar records are available, and secondly the chief sources of infection appear to be defecation spots in the vicinity of the homes of the people.

B. Analysis of the groups included in this section.

1. *The coastal plains area (Chorrerita, El Coco and Cocle).*

a. General discussion.

As stated in the first section a large proportion of the people in Panama live on the coastal plain of the Pacific coast. Most of this

plain is a typical cattle country with wide open spaces and sparse vegetation. The people except in the larger towns usually live in scattered villages where the individual house or small group of houses is the unit rather than the village as a whole. In fact the term "village" as applied to these communities is really equivalent to our usage of the term "township." Most of the land is used for grazing and the cultivation usually consists of small plots of vegetables or grain near the houses. The untreated individuals of the unsanitated villages of Chorrerita, El Coco and Cocle are taken to represent the situation in the rural coastal plains when uninfluenced by the control campaign.

The description of the Penonome district and of these villages in particular which was given in Section I will not be repeated here. In presenting the results of our epidemiologic studies we will first give an account of the soil pollution surveys, second the results of the soil infestation studies and third an analysis of the egg counts according to age, sex, and other factors pertinent to the discussion.

b. Soil pollution and soil infestation studies.

(1) Introductory statement.

Of the three villages included in this area, cover in the form of trees and bushes was found most frequently near the houses in Chorrerita and least frequently in Cocle. Chorrerita was nearer the hills and somewhat hilly while El Coco and Cocle were quite flat. The houses were widely scattered in all three places. Different houses of the same village offered as wide variations in all the conditions related to our problem as any of the houses of the separate places. Soil pollution and soil infestation studies were made at these three places in the summer of 1926 in late June, in July and in the early part of August which is the early part of the rainy season with moderate rains almost every afternoon. The people made no attempt to conceal the places of soil pollution, and on this account and because of the limited amount of cover near the houses it was usually comparatively easy to learn the defecation habits of any given household. None of these villages had been influenced by the sanitary program. No latrines had been built for the houses, and there were only a few concentrated pollution spots of the type called "natural latrines" (Cort and Payne, 1922*b*). Some beginning of a sanitary sense was perhaps indicated by the fact that the adults usually sought defecation places at considerable distances from the houses and apparently attempted, although not always successfully, to keep the children

from depositing their stools in the immediate neighborhood of the houses.

Rather extensive soil infestation studies were carried out by the examination of soil samples with the Baermann isolation apparatus. These studies gave certain results of interest but proved to be of somewhat limited value since the positive results in most cases only served to confirm what could as well have been assumed from the presence of stools in favorable locations. Further the wide scattering of the stools in most of the places made it almost impossible to interpret the negatives, since the absence of larvae in any given sample might be due to a failure to locate a particular place where pollution had been present at the proper interval before the sampling. In connection with the difficulty of locating soil infestation from scattered stools it should be recalled that infective hookworm larvae do not migrate actively from their place of development so that isolated "nests" of infective larvae are formed (Augustine, 1922, Cort and Payne, 1922*a*). We will first give briefly the results of the soil pollution and soil infestation studies in each of the three villages included in this area and then sum up the common features.

(2) Chorrerita.

There were in general four different types of pollution spots found in Chorrerita. At some of the houses there were no thickets or groves near enough to afford cover. At such places the stools were usually widely scattered, in a few cases in gulleys or on bare hillsides but often on level, grassy places at varying distances outside the yards. Where cover was available it was usually utilized by adults, who sometimes travelled to a distance as great as 300 yards to find suitable places for defecation. If the cover was near it would also be visited by the children. But often widespread pollution areas visited chiefly by the children would be present in nearby open places in addition to the more distant shaded places. Soil pollution studies were made at a total of thirty-four houses in Chorrerita. At fourteen of them where no cover was accessible the only traces of stools found were those scattered in exposed places. At several of these places the stools were scattered on bare hillsides or in gulleys, where conditions were unfavorable for soil infestation. The most characteristic situation, however, was the scattering of the stools in grassy places where the height of the grass varied from an inch or so to a foot. A total of 47 soil samples were examined from 14 different exposed areas where stools had been found. Of these 11 were positive yielding infective

hookworm larvae as follows: (1) 1, (2) 1, (3) 1, (4) 2, (5) 11, (6) 29, (7) 51, (8) 163, (9) 233, (10) 250, (11) 586. Considering how widely the stools were scattered and the chances of missing the "nests" of larvae under such conditions, the finding of even these comparatively small numbers of larvae indicate that soil pollution in such grassy places, even where there is no shade, is favorable for the development of soil infestation.

At 20 of the houses shaded pollution areas were found. At four of these there was a concentration into "natural latrines." Such concentration is probably less dangerous since the actual polluted ground is less accessible than the more usual situations where the stools are widely scattered in areas protected by groves or thickets. At 17 houses such shaded pollution areas were found at distances from the houses varying from 10 to 200 yards. Here also soil sampling was somewhat uncertain on account of the scattering of the stools. At many of these houses there were also exposed areas of scattered pollution, often used by children when the shaded areas were at considerable distances. Seventy-six soil samples were taken from 17 such shaded areas, where the soil was almost always a loose loam or humus and the moisture was well conserved, making conditions that appeared to be very favorable for the development of hookworm larvae. Twenty-four of these soil samples were positive, eight of which gave fairly large numbers of infective larvae as follows: (1) 248, (2) 250, (3) 400, (4) 800, (5) 1,000, (7) 2,220, (8) 9,550. The finding of such numbers of hookworm larvae in soil samples from areas where the stools are widely scattered indicates a widespread and heavy soil infestation.

(3) El Coco.

Soil pollution and soil infestation surveys were made for 38 houses in the village of El Coco. For 22 of these, the pollution areas found were unshaded and there was no cover near enough to the houses for ordinary use. At 19 of these 22 houses definite grassy areas were utilized. Such areas were also found at some of the places where shaded spots were within reach of the house. Therefore at El Coco the most common situation for the depositing of stools was the grassy plot where they were usually widely scattered. The uncertainty of soil sampling at such places has already been noted. During our visits to El Coco 43 soil samples were taken from polluted grassy situations. Twelve of these were positive of which the heaviest five gave numbers of larvae as follows: (1) 36, (2) 39, (3) 64, (4) 244, (5) 511. Here again as in Chorrerita we have a demonstration of

the fact that exposed grassy areas are to some extent at least favorable for the development of hookworm larvae.

At sixteen of the houses in El Coco there were places of definite cover near enough to the houses to be visited for purposes of defecation. At most of these houses the cover within reach was of considerable extent so that the stools were almost always widely scattered, and at only two houses was a concentration found approaching a "natural latrine." Forty-five soil samples were taken from various shaded places where pollution was found. Fifteen of these were positive, with the heaviest counts as follows: (1) 335, (2) 398, (3) 400, (4) 412, (5) 645, (6) 1,850, showing as in similar places in Chorrerita a widespread soil infestation.

(4) Cocle.

The scattered houses of the village of Cocle were on the open plain where there was little cultivation and very much less cover, than was found at either Chorrerita or El Coco. Most of the soil pollution found around the houses of this village was either scattered widely over grassy areas or deposited in the gulleys which were quite numerous. The first of these situations has been shown to be favorable for soil infestation. The second would seem to be much less dangerous since the gulleys were almost comparable to latrines in that the people would have little if any contact with the polluted soil. At a few places in Cocle pollution was found either concentrated or scattered in shaded places where the conditions were favorable for the development of soil infestation. Seven soil samples from such places gave five positives with 11, 27, 155, 210 and 463 infective larvae respectively.

(5) Summary of soil pollution and soil infestation conditions in the coastal plains type of situation as represented by Chorrerita, El Coco and Cocle.

The soil pollution and soil infestation conditions at the villages of Chorrerita, El Coco and Cocle have been discussed in some detail since they appear to be typical of the conditions of a large proportion of the population of Panama who live on the coastal plains of the Pacific littoral. Infestation of the people with hookworms is heavy even where there is no cover near the houses, probably because the constant scattering of stools in grassy areas around the houses would pile up during the long rainy season a circle of infective larvae which would be picked up in the various activities of the people. It is of interest in this connection that Korke (1925) concludes from his studies that unshaded ground covered with grass and vegetation is

the most favorable type of environment for the development of hookworm larvae. Some concentrated defecation spots were present where the adults and sometimes the older children visited constantly clumps of trees or bushes, often at considerable distances from the houses. Here the infection of the people as well as the infestation of the soil would be dependent on the habit of defecation. When the stools are widely scattered in shaded groves or thickets the soil infestation would in the course of the rainy season become very widespread and intense. These areas would be particularly dangerous when near the houses since not only the defecation habits but also any activities which would bring the people into such places would produce infection. It would appear, therefore, that most of the worm burdens of the people of these villages could well come from the pollution near their houses. There remain, however, possibilities of the acquisition of infection away from the houses. In the area under discussion especially in Cocle some of the families cultivate plots in the hills often at considerable distances from their houses. This adds a probable additional source of infection especially for the men who do most of this work away from home. Another difference in defecation habits between the men on one hand and the women and children on the other is that in the latter group chambers are often used which are emptied at convenient places, usually where people would not readily come in contact with the soil thus polluted.

c. Analysis of the egg counts for Chorrerita, El Coco and Cocle.

(1) Total group according to age and sex.

The villages of Chorrerita, El Coco and Cocle had been untouched by the hookworm control work except that a considerable number of people in El Coco and a few in the other two places had received dispensary treatments about four years before our study. A discussion of the effects of the El Coco treatments will be given in the next section so that the treated group need not receive further consideration here. We will, therefore, use for the analysis the 390 untreated cases from these three villages out of a population of approximately 750, considering them to be representative of the level of hookworm infestation, characteristic of the rural districts of the coastal plain. In this group there were included 193 males and 197 females with an unusually good representation of the younger age groups. The examination of this group with a combination of the dilution count and Willis method (see Section II) gave 344 (88 per cent.) positive for hookworms. Of the 46 negatives 39 were under 5

years of age and 30 in the age group from zero to 2 years, giving an incidence in those 5 years of age and over of 97.8 per cent. and for those 3 years or over 95.4 per cent. The average egg count for this group as it stands is 11,560 eggs per c.c.,* with the average for the males at 13,100 and for the females at 10,060. These averages were corrected for a standard age distribution using the census of 1910 for Porto Rico as suggested in Section IV. The corrected average for the males was 14,150, for the females 10,210 and for the combined males and females 11,650 indicating that the age and sex distribution in our original groups was quite satisfactory. Chandler (1926) has proposed a method of arriving at an index of infestation for a group which takes into account both incidence and degree of infestation. According to his method the index for Chorrerita, El Coco, Cocle group is 927 for the males, 838 for the females and 884 for the whole group. Since the differences between the infestations in males and females runs constantly through the whole group the sexes will be considered separately in the further analysis. In considering the division according to age groups the most natural arrangement that suggests itself is 0–4, 5–14, 15–49, 50+. The 0–4 group represents the youngest children who are largely confined to the neighborhood of the houses. The 5–14 group represents the school age, during which period there is but little difference in the activity of the sexes. In the 15–49 group the males are engaged in labor in the field or in the care of cattle and the females chiefly in household duties and the rearing of children. Finally after 50 years both sexes tend to be more closely confined to the houses. This last group in most cases contains such small numbers that it will not usually be considered separately.

TABLE 1.

Analysis of the hookworm infestation of the coastal plains area (Chorrerita, El Coco and Cocle) according to the natural age groups.

Age groups.	Males.		Females.	
	No. of cases.	Av. egg count per c.c.	No. of cases.	Av. egg count per c.c.
0–4	44	1,670	32	2,630
5–14	48	10,490	51	10,150
15–49	81	19,530	94	13,140
50+	20	18,460	20	7,230
Total	193	13,100	197	10,060

* All egg count figures are on the "basis of formed feces" (see Section II).

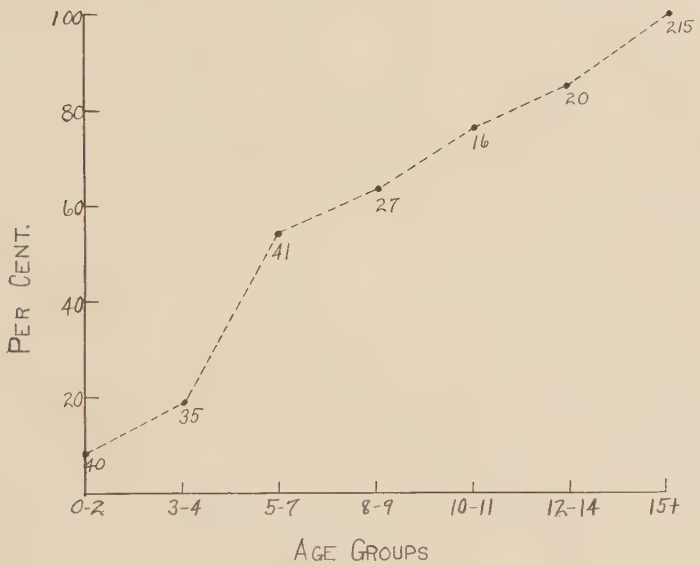
Table 1 shows the average egg counts for these age groups. As shown in Section III the egg counts for children under 10 years of age and especially in the 0–4 group have to be somewhat discounted on account of the small size of the stools which produces a concentration of eggs. This point should be kept in mind whenever egg counts for young children are considered. There are no significant differences between the infestations of males and females up to 15 years. Above this age the differences become very pronounced suggesting that there is a definite difference in exposure to infection. The differences in infestation of the males and females might be explained by two differences in activity. In the first place many of the men are engaged in agricultural and other pursuits away from home which probably in some cases at least give an additional exposure to hookworm infection superimposed on that from the environment of their houses. An illustration of this was afforded by a family in Chorrerita all of whom with one exception carried moderate infestations. The exception was a very heavily infested young man who worked habitually in a field some distance from the house. At the side of this field was a large tree which afforded deep shade and under which was found a heavy soil infestation coming from frequent visits of laborers. Contact with such a place probably explains the heavier infestation of this individual as compared with the rest of the family. The second difference, which in most cases is probably the most important, is that at least some of the females do not always visit the pollution spots, especially when they are at considerable distances, but, as already noted, may defecate in chambers which are usually emptied at places where there would be little if any possibility of infection from the larvae which might develop. Since the age group of 50 years and over is comparatively small in numbers it is difficult to be sure whether or not the peculiarities in the averages for this group (Table 1) have any general significance or not.

In the same way it is difficult to be certain of the explanation of the differences between the males and females which are found when an analysis is made according to 10 year age groups (Table 2). Here the differences are very great in the 20–29 year group where the males would be at their maximum activity and the females would be most closely confined to the houses by the bearing of children and their care. It is, however, more difficult to offer any explanation for the great decrease of the differences between the sexes in the groups from 30–49 years except to suggest that the women after 30 tend to assume more the field activities of the men following the most active

TABLE 2.

Analysis of the hookworm infestation of the coastal plains area (Chorrerita, El Coco and Cocle) according to ten year age groups.

Age groups.	Males.		Females.	
	No. of cases.	Av. egg count per c.c.	No. of cases.	Av. egg count per c.c.
0–9	75	4,690	65	5,690
10–19	31	16,340	40	12,250
20–29	30	23,120	24	12,050
30–39	21	15,390	28	13,030
40–49	16	17,710	21	15,390
50–59	9	18,140	6	9,070
60+	11	18,710	14	6,430
Total	193	13,100	197	10,060



GRAPH 1. A representation of the rate of acquisition of hookworm infestation in children of the coastal plains group (Chorrerita, El Coco and Cocle). The average egg count for each age group is given as a per cent. of the average adult count (15 years and over). In the 0–2 group one doubtful heavy case of 29,800 eggs per c.c. recorded in a child under one year of age is removed, since it probably represents a substitution of fecal samples. In graphs 1 to 3 the figures at each point in the curves represent the number of cases used in computing the value.

child bearing period. Also the much lower average infestation of the women after 50 years of age as compared to the men might be ascribed to a continuance into later life by the men of field work and related activities. In the same way the high peak in the men might be ascribed to the peak of activity of the 20–29 age group and the peak in the women in the 40–49 group to increased activity outside the house after the close of the child bearing period. It must, however, be again emphasized that the averages of such small groups may be badly upset by a few heavy cases.

The rate of acquisition of the infestation in the children is shown in Graph 1 which gives the per cent. of the adult average (15 years and over) of the egg count averages for each age group. This shows that

TABLE 3.

Intensity groups for Chorrerita, El Coco and Cocle.

Males.

Infestation groups in eggs per c.c.*	0–14		15+		Total.	
	No.	Per cent. of age group.	No.	Per cent. of age group.	No.	Per cent. group.
Negative	25	27	2	2	27	14
100–999	11	12	4	4	15	8
1,000–4,999	30	33	18	18	48	25
5,000–9,999	9	10	24	24	33	17
10,000+	17	18	53	52	70	36
Total	92		101		193	

Females.

Negative	17	20	2	2	19	10
100–999	8	10	7	6	15	8
1,000–4,999	26	31	36	31	62	31
5,000–9,999	14	17	18	16	32	16
10,000+	18	22	51	45	69	35
Total	83		114		197	

* These infestation groups differ somewhat from those used in earlier publications from this laboratory (Payne, Cort and Riley, 1923 and Cort, Grant and Stoll, 1926). It was thought best to simplify them as much as possible. They are not considered to necessarily represent natural groups although the first positive group can undoubtedly be classed with the negatives, the next two can be considered of doubtful clinical significance, while the last probably contains most of the clinically severe hookworm cases.

by seven years of age the children have more than half the adult egg count, and that by their 14th year it is not far below the adult average.*

Table 3 gives the cases in this series analyzed according to certain arbitrary infestation groups. A surprisingly large number of the cases fall into the group with egg counts of 10,000 eggs per c.c. and over. Infestations of this type would ordinarily be considered of considerable clinical significance. Among the heaviest cases the number of males greatly predominates, since there are 10 males and 2 females who have counts of 50,000 eggs per c.c. or more. The excess of these heaviest cases among the males to a considerable extent accounts for the heavier average infestation among the adult males as compared with the adult females, since the distribution in the infestation groups is about the same. The record for this series was a male in the 20–24 year age group with a count of 51,000 eggs per c.c. of mushy specimen or 102,000 basis formed.

(2) An analysis of the egg count averages in respect to two types of pollution areas.

In these three villages there were seen to be two general types of situations with relation to soil pollution, (1) those in which there were found no shaded pollution areas and (2) those in which the availability of cover produced such areas which were constantly visited by the adults. Of the three villages Chorrerita had the most cover of trees and bushes within reasonable reach of houses and Cocle the least. It is possible that the considerable difference in the level of infestation in these two villages was due to this fact and the consequent differences in the type of soil pollution and infestation areas which were produced (see Table 4).

To check further the effect of the presence of cover near the houses on the average infestation, a comparison was made of the average egg counts at those houses in Chorrerita and El Coco where there were found shaded pollution spots with those where the pollution was widely scattered in unshaded places. The treated as well as the untreated cases in El Coco are included in this analysis. While the results of this comparison are not clear cut and the number of cases is rather small, they are presented as a suggestive piece of evidence on the greater danger of infection from shaded pollution spots. In the group which lived in houses where there was nearby cover, under which shaded pollution spots were found, the 45 males

* Here again it must be noted that the count in the children is exaggerated on account of smaller stools. In the series considered in Section III the stools of children under 3 years were one fourth and those between 3 and 5 one half the adult size.

15 years of age and over, had an average egg count of 27,490 eggs per c.c. and the 46 females a count of 11,440, while at the houses with no cover where the pollution spots were unshaded the 30 males had

TABLE 4.

Comparison of the average egg counts in two villages in one of which (Chorrerita) shaded pollution areas were common, and in the other (Cocle) very little shade was present.

Age groups.	Males.		Females.	
	No.	Average egg count.	No.	Average egg count.
Chorrerita.				
0–4	17	560	14	2,660
5–14	23	12,070	26	12,330
15+	39	21,920	58	13,140
Total	79	14,460	98	11,430
Corrected average		15,730		11,320
Cocle.				
0–4	8	1,140	8	750
5–14	18	9,280	13	9,680
15+	34	12,740	34	12,040
Total	60	10,190	55	9,840
Corrected average		9,780		9,800

an average of 14,330 and the 34 females 11,860. This at least suggests that the males who most frequently visit rather distant shaded pollution spots are more exposed to infection than those who live where such spots are not available. While such shaded spots may be no more favorable for the development of the infective larvae than the grassy places, as suggested above, the tendency for the pollution in the grassy places to be more scattered may render them somewhat less dangerous than the more limited shady places.

2. *Sardina and Marica Arriba, a hilly area at the edge of the coastal plains.*

a. Soil pollution and soil infestation studies.

Sardina and Marica Arriba were two hill villages within a short distance of Penonome. The situation at these places has been out-

lined in Section I and the location of the houses is shown in Map III of that section. Certain peculiarities in these areas need emphasis here. The amount of cultivation around the houses was unusually great since the people were the truck gardeners for the town of Penonome, and trees and bushes were so frequent that every house had cover either in the yard itself or nearby. This made for conservation of moisture and produced a situation in which there were almost always numbers of shaded places near the houses where conditions of the soil would be very favorable for the development of hookworm larvae. In Marica Arriba there had been no attempt at sanitation whatever while at Sardina latrines had been established about six months before our survey was made. A discussion of the sanitary conditions in Sardina will be given in the next section. Since the latrines had been introduced so recently and the level of infestation was so high, the small influence that they had probably exerted in the short time they had been in use can be ignored and Sardina will be combined with Marica Arriba as representing the situation in an untouched area in the hills at the edge of the coastal plain. It must be further noted, however, that a number of people in these two areas had received dispensary treatments at Penonome three or four years before. As is shown in the next section the effect of these treatments had almost entirely disappeared. On account of the sanitation in Sardina and the treatments in both places it is probable that even the high level of infestation which we found is somewhat below what it must have been before the influence of the hookworm control campaign.

It seems probable that the conditions of soil pollution in Sardina before the introduction of latrines were like those of Marica Arriba since the general situation, the cultivation around the houses and the amount of available cover in the two places is very much the same. At the few unsanitated houses in Sardina and elsewhere in this village where soil pollution was found the conditions were comparable to those in Marica Arriba. We will, therefore, consider the findings on soil pollution and soil infestation in this place as in general applicable to Sardina also.

The soil pollution and soil infestation studies at Marica Arriba gave information which made it possible to understand how such a high level of hookworm infestation as that found in these two villages could be built up. Every house in this village was entirely unprovided with latrine accommodations and the pollution of the soil was found to be widespread in every situation investigated. The houses were a

considerable distance apart (see Section I, Map III) so that most of them appeared to be units as far as the dissemination of hookworm was concerned. Most of the adults went to some little distance from the houses to deposit their stools and pollution areas were found at distances up to almost a hundred yards, although due to the abundance of nearby cover most of the pollution places were much nearer to the houses than at El Coco or Chorrerita. There were almost no spots in this village where the concentration of pollution was of the type to which the name "natural latrine" has been given. There were a number of what might be called pollution areas where the stools were scattered over definite areas often of considerable size. For the most part, due probably to the abundance of convenient cover in the vicinity of the houses the people did not habitually visit a definite place or area but scattered their stools very widely in the neighborhood of their houses. It was not an unusual thing on one visit to a house to find three or four separate defecation spots often in entirely different directions. A rather common type of pollution area found at Marica Arriba was an open, grassy glade usually at a considerable distance from the house and sheltered from it by trees or bushes. Such places might be used continually by a whole family and in one case at least it was shared by two families. Around the edge of one such glade evidences of about a dozen pollution spots were found. Of the 17 houses in this village included in this survey such grassy glades were found at eight as the major or only pollution areas. They were almost all surrounded by a fringe of bushes and the stools were usually deposited along the edges. Although there was very little shade the soil was well protected by a thick covering of grass and at the time of collection of the soil samples, which was usually in the late morning, the soil obtained was quite moist. A total of 25 soil samples were examined from four places of this type. From nine of them infective hookworm larvae were obtained in the following numbers: (1) 16, (2) 180, (3) 183, (4) 230, (5) 810, (6) 1,240, (7) 1,380, (8) 1,700, (9) 10,000. When it is considered that the stools at these places were widely scattered and that traces of them disappeared quickly, it is evident that such soil sample records indicate a widespread intense soil infestation.

The most characteristic type of soil pollution in this village, however, was the scattering of stools in well protected shady places near the houses. There were few if any places of such concentration as to suggest the constant visiting of a particular spot. Rather the people seemed to go almost at random to almost any protected shaded

place near the houses. Thirty four soil samples were taken from places of this type near eight houses. Here also the scattering of the stools made the location of infective larvae pretty much a matter of chance. Twenty two of these soil samples were positive, eight with less than 100 larvae each, nine with 100 to 1,000 and the others with the following numbers: (1) 1,300, (2) 1,300, (3) 3,930, (4) 6,240, (5) 9,200. With such an amount of soil infestation gradually becoming heavier and heavier as the long rainy season grew older and coming to be more and more widely scattered around the houses, it is no wonder that such a high level of hookworm infestation was built up. Each house would come to be surrounded by more and more "nests" of larvae, until toward the end of the rainy season there would be greater and greater chances of coming in contact with the larvae by people visiting these areas for defecation or other purposes. With the loose soil and dense shade of many of these places, the larvae probably persist long into the dry season and the period of time each year when the soil would be sterilized by drying would be greatly reduced. It seems also improbable that any short periods of drought which occurred during the course of the rainy season would be enough to sterilize these shaded areas of soil infestation.

b. Human infestation at Sardina and Marica Arriba.

The combined census of the villages of Sardina and Marica Arriba was 230 people and samples from 214 were examined. Of these 188 individuals or 87.9 per cent. were positive. Most of the negatives were in children under three years of age since in the group three years of age and over there were only 6 negatives or a per cent. of infestation of 97.2. There was only one negative in the group of five years of age and over and no negatives in the groups over seven years. It becomes apparent that in population groups with this type of infestation incidence statistics are of little value in making comparisons because the percentage of negatives would depend so much on the number of individuals included in the examinations under five years of age.

The average egg count for Sardina and Marica Arriba is 16,490 eggs per c.c., the 114 males having an average count of 20,470 and the 100 females of 12,120. The corrected average count for the males was 20,530, for the females 13,740, and for both the males and females 17,130. Here again the correction of the averages according to age and sex distribution in a standard population makes but slight changes in the averages. The analysis according to the natural age groups

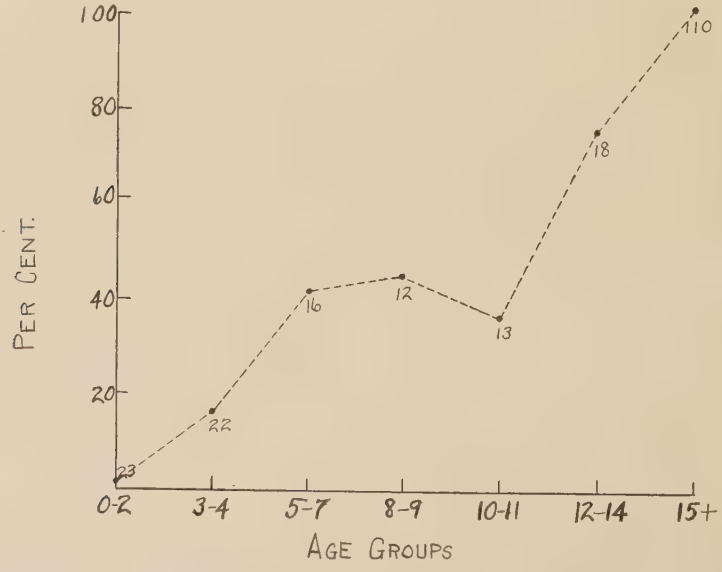
shows that the school children have about half the adult infestation. It also brings out clearly the differences between adult males and females (Table 5). The numbers in this group are too small to make

TABLE 5.

Analysis of the hookworm infestation of the Sardina-Marica Arriba group according to age and sex.

Age group.	Males.		Females.	
	No. of cases.	Av. egg count per c.c.	No. of cases.	Av. egg count per c.c.
0–4	17	2,250	28	1,980
5–14	36	13,880	23	10,900
15+	61	29,430	49	18,480
Total	114	20,470	100	12,120
Corrected average		20,530		13,740

analysis into small age groups of any particular significance. We will present, however, the analysis showing the acquisition of infestation (Graph 2).



GRAPH 2. A representation of the rate of acquisition of hookworm infestation in the children of Sardina and Marica Arriba. The average egg count for each age group is given as a per cent. of the average adult count (15 years and over).

The severity of infestation in these villages is further emphasized by the analysis into intensity groups (Table 6). Here as well as in

TABLE 6.

Intensity groups in Sardina and Marica Arriba.

Males.

Infestation groups.	0–14		15+		Total.	
	No.	Per cent. of age group.	No.	Per cent. of age group.	No.	Per cent. of age group.
Negative	10	19			10	9
100–999	2	4			2	2
1,000–4,999	7	13	6	10	13	11
5,000–9,999	9	17	10	16	19	17
10,000+	25	47	45	74	70	61
Total	53		61		114	

Females.

Negative	16	31			16	16
100–999	8	16	2	4	10	10
1,000–4,999	10	20	7	14	17	17
5,000–9,999	6	12	11	23	17	17
10,000+	11	21	29	59	40	40
Total	51		49		100	

the average egg counts the differences between the males and females is clearly brought out. Here again the only suggested explanations are those given for the previous group. Since this area has the largest number of extremely heavy cases ever recorded by the egg counting method for any group of people we will list those over 40,000 eggs per c.c. (Table 7). Here again the great preponderance of these heavy cases in the males accounts in large part for the higher average infestation in the males than in the females. The man listed in Table 7 forty years of age with an egg count of 208,400 eggs per c.c. is the highest individual egg count we know of being recorded by the dilution counting method. In estimating the number of worms in this case the actual count must be somewhat discounted because at the time of this first examination his stool was exceptionally hard since he was very badly constipated. A somewhat more normal stool from this same individual examined nine days after the first examination

gave a count of 139,100 eggs per c.c. After treatment of 2 c.c. of carbon tetrachloride a reexamination gave an egg count for this individual of 24,600 eggs per c.c. Unfortunately it proved to be impossible to obtain a worm count. Two other individuals lived at

TABLE 7.

List of cases in Sardina and Marica Arriba with egg counts over 40,000 eggs per c.c.

Males.		Females.	
Age.	Count.	Age.	Count.
12	64,400	16	40,600
17	53,200	16	46,000
19	41,200	16	125,600
19	42,400	54	72,400
20	46,600		
20	59,000		
20	63,600		
20	102,000		
25	77,100		
35	47,000		
40	208,400		
45	73,600		
50	40,000		
60	107,200		
85	42,800		

the same house with this man, a woman 35 years of age with an egg count of 11,800 eggs per c.c. and a four year old boy who was negative. The man stated that he had lived 40 years in the same house. There was nothing in the situation at the time of our study to explain the enormous infestation of this individual. He was in fact using an exposed pollution spot where conditions were unfavorable for the development of hookworm larvae.

3. *La Soledad, an upland village.*

a. Soil pollution and soil infestation.

La Soledad is taken to represent the rural conditions of the Santiago districts, typical of the uplands of Panama. The rainfall of these regions is over 100 inches a year, which with a fertile soil develops the type of vegetation which we have come to consider typical of the tropics. La Soledad which has been described and mapped in Section I is more a village unit than the rural areas of the Penonome district.

In and surrounding the yards about the houses there is a profusion of trees and shrubs, making an abundance of cover easily accessible, where the soil is almost constantly wet during the long rainy season. An entire absence of latrines in this village combined with such a favorable environment at the places of pollution for the development of hookworm larvae has raised the infestation of this place to a very high level. There seems to be no reason to believe, however, that the level for La Soledad is anything but typical for those regions of Panama where environmental conditions are similar, and it is in fact only slightly higher than that of Sardina and Marica Arriba. The people of La Soledad are for the most part very poor, undernourished and quite anemic. The distribution of soil pollution is influenced by the fact that there is such dense cover near the houses. The children tend to pollute the soil near the houses and their stools are usually considerably scattered. Pollution spots and areas visited by adults were found at a number of places from 50 to 200 feet back of the houses, in some places adjoining houses using such areas in common. The stools were widely scattered with little tendency to the development of concentrated spots. It seems probable that with so much convenient cover there would be a constant shifting of the pollution areas from season to season or in the same season. During our visits when the rainy season was approaching its height the soil in these places, which was a sticky clay with sometimes a sandy intermixture, was always quite wet. The amount of vegetation usually produced a layer of humus over the clay. All in all the conditions seemed quite ideal for the development of hookworm larvae. The dense shade would also tend to such a conservation of moisture, that it seems probable that the soil would retain some moisture for a considerable part of the dry season.

Even here where there was so much cover the tendency of the adults to seek places at a distance from the houses appeared to be an attempt to keep the immediate yard clean. Practically all the stools found at the time of our survey were in definitely shaded places, and a larger proportion of the stools appeared to be deposited on places favorable for the development of hookworm larvae than at any of the other situations studied in Panama. Compared with such a place as Chorrerita the pollution areas are not so definitely defined and tend to be closer to the houses. The situation affords even greater cover than at Marica Arriba although the conditions in these two places are quite comparable.

All the soil samples examined from La Soledad were collected

during one trip taken on August 17, 1926. There had been an unusually heavy rain the previous day and the ground was saturated and the trees and bushes dripping. The clay soil was quite sticky and for every single sample taken the record of the soils was made either as wet or very wet. Our experience has been that under such conditions it is difficult to secure soil samples which give a true picture of soil infestation. We may, therefore, consider that the records of the soil samples taken from La Soledad do not represent a true picture of the amount of soil infestation. Of the thirty soil samples secured on this trip 11 were positive with numbers of larvae ranging from 60 to 1,740. It was impossible to make further collections from La Soledad since it was so far from our base laboratory, but the high level of hookworm infestation plus the widespread soil pollution in such favorable places indicated a widespread and intense soil infestation.

The studies on soil pollution and soil infestation from the scattered houses of La Atalaya (for description and location see Section I), which were unprovided with latrines, or where gross soil pollution persisted in spite of latrines may also be included here as representative of this same general region. The rest of the discussion of the La Atalaya situation will be reserved for Section VI since it gives some interesting information on the effect of treatment and sanitation. A large part of the houses at La Atalaya were grouped around a central square and were practically all provided with latrines. Of fourteen of the houses at a distance from the square which were visited four were without latrines and the conditions at almost all of the others were comparable to those in entirely unsanitated areas. Besides areas of scattered pollution around these houses most of which were well shaded, there were found at considerable distances places where the pollution was considerably concentrated. The largest area of this kind was along a path in a grove. A large number of stools were found here and the place was apparently used not only by the people in nearby houses but also by people passing along the path. There was every chance of contact with infested places both for people visiting the place for the purpose of defecation and for those merely passing along the path. How great a menace such a place might be was indicated from the examination of three soil samples which yielded respectively 60, 340 and 4,140 infective hookworm larvae. Infective larvae ranging in numbers from 20 to 1,000 for each sample were obtained from a number of samples taken from shaded polluted spots or areas visited by the people from the outlying houses of La Atalaya.

At most of the places the conditions of soil, shade and moisture were so favorable that even a few scattered stools would produce dangerous nests of larvae. Here again the accumulation of soil infestation during the progress of the long rainy season would become more and more dangerous and it is not at all surprising that the people who habitually visited these places showed extraordinarily heavy worm burdens.

b. Human infestation at La Soledad.

With the environmental factors and personal habits so favorable for hookworm dissemination as those just described an unusually high level of hookworm infestation would be expected at La Soledad. Some of the people of this village had received dispensary treatment in 1919 and 1920, but no effect could be demonstrated at the time of our study by comparing their egg counts with those of others of the same age groups who had not received treatment (see Section VI). We, therefore, use La Soledad as representative of the original level of infestation for the rural upland areas of Panama, characterized by heavy rainfall and an abundance of vegetation near the houses.

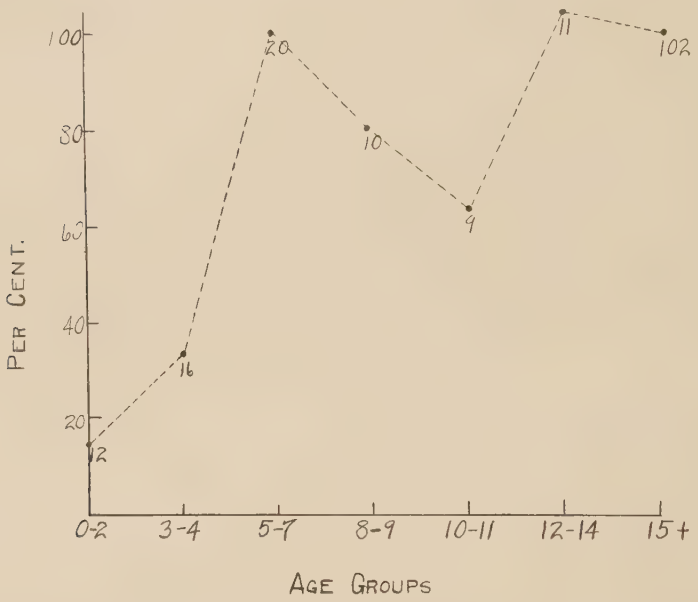
The census of La Soledad at the time of our survey was 196 and samples for examination were obtained from 180 people. The average count for the whole group was 17,450 eggs per c.c. The average for the 102 males was 20,760 and for the 78 females 13,130. The corrected counts made but little change in this group giving an average of 20,740 for the males, 13,050 for the females and 16,890 for the whole group. The numbers are too small to make any detailed analysis into the smaller age groups, but when the three natural groups are used (Table 8) it is seen that the infestation in the very young children is unusually heavy, that that of the school children is practically on the same level with the adults.

TABLE 8.

Analysis of the egg counts from an upland village, La Soledad, according to age.

Age groups.	Males.		Females.	
	No. of cases.	Av. egg count per c.c.	No. of cases.	Av. egg count per c.c.
0–4	16	6,790	12	3,430
5–14	25	21,390	25	15,450
15+	61	24,160	41	14,560
Total	102	20,760	78	13,130
Corrected average		20,740		13,050

An early acquisition of heavy infestation is shown in Graph 3 which gives the average infestation in the children in percentages of the adult (15 years and over) average.* The high average of the 5 to



GRAPH 3. A representation of the rate of acquisition of hookworm infestation in the children of La Soledad. The average egg count for each group is given as a per cent. of the average adult count (15 years and over).

7 year group is worthy of especial note. It is about the same in males and females and is not brought about by a few very high counts since 11 out of the 19 individuals in this group have counts of 20,000 eggs per c.c. or greater. Such heavy infestations in children as young as these, which are greater than any ever recorded elsewhere, can only be accounted for by early exposure to the soil infestation of pollution spots used by adults, which at this village were easily accessible on account of the large amount of cover near the houses.

The extreme character of the infestation in La Soledad is again emphasized when analysis is made according to the infestation groups (Table 9), since 62 per cent. of the total number have infestations over 10,000 eggs per c.c. The much smaller proportion of females than males in this category again illustrates clearly the difference between the sexes.

* The qualification noted above in regard to the effect of stool size on the children's egg count would of course apply here.

TABLE 9.

Intensity groups for La Soledad.

Males.

Intensity groups.	0–14		15+		Total.	
	No.	Per cent. of age group.	No.	Per cent. of age group.	No.	Per cent. group.
Negative	5	12			5	5
100–999	3	7	1	2	4	4
1,000–4,999	4	10	5	8	9	9
5,000–9,999	5	12	5	8	10	10
10,000+	24	59	50	82	74	72
Total	41		61		102	

Females.

Negative	4	11			4	5
100–999	2	5			2	3
1,000–4,999	5	14	6	15	11	14
5,000–9,999	13	35	10	24	23	29
10,000+	13	35	25	61	38	49
Total	37		41		78	

Table 10 gives a list of cases with counts of over 40,000 eggs per c.c. The large number of such cases and the great preponderance of males are worthy of note.

TABLE 10.

List of cases of 40,000 eggs per c.c. or over for La Soledad.

Males.		Females.	
Age.	Egg count.	Age.	Egg count.
8	42,800	5	43,800
13	48,000	24	40,600
17	50,700	50	53,900
19	44,800		
28	84,800		
34	56,200		
36	40,200		
45	40,400		
50	56,700		
52	61,500		
65	43,200		

4. *A combined analysis of Sardina, Marica Arriba and La Soledad.*

The Sardina and Marica Arriba series as compared with La Soledad shows about the same level of infestation as well as comparable differences between the males and females. The two series differ in that in La Soledad the infestation is much more rapidly acquired (cf. Graphs 2 and 3) and also in that the high average in this place is produced by a very general heavy infestation and not influenced quite so much by a few heavy cases as in Sardina and Marica Arriba. The combination of these two groups is made for certain points of analysis especially related to the adult infestation. Such a combination group may be considered to be representative of the hill or upland type of hookworm infestation in Panama, as compared with the coastal plains represented by the Chorrerita-El Coco-Cocle group.

TABLE 11.

An analysis according to age groups of the egg counts for the combined areas of Sardina, Marica Arriba and La Soledad, as typical of the upland regions of Panama.

Age groups.	Males.		Females.	
	No. of cases.	Av. egg count.	No. of cases.	Av. egg count.
0–9	63	9,320	68	7,700
10–19	59	20,730	37	17,580
20–29	30	29,680	24	15,880
30–39	25	20,880	23	11,430
40–49	17	34,650	18	12,470
50–59	11	23,070	6	32,020
60+	11	35,030	2	9,250
0–4	33	4,450	40	2,410
5–14	61	16,960	48	13,270
15+	122	26,790	90	16,700
Total	216	20,600	178	12,560
Corrected average		20,610		13,520

Table 11 gives the infestation of this combination group according to sex in 10 year age groups and the natural age groups. It will be helpful to have also for this combined group the analysis according to intensity groups, as shown in Table 12. The index for this group which has been worked out according to Chandler's (1926) method is 1,308 for the males, 967 for the females and 1,155 for the sexes combined.

TABLE 12.

Intensity groups in Sardina, Marica Arriba and La Soledad.

Males.

Intensity groups.	0–14		15+		Total.	
	No.	Per cent. of age group.	No.	Per cent. of age group.	No.	Per cent. group.
Negative	15	16			15	7
100–999	5	5	1	1	6	3
1,000–4,999	11	12	11	9	22	10
5,000–9,999	14	15	15	12	29	13
10,000+	49	52	95	78	144	67
Total	94		122		216	

Females.

Negative	20	23			20	11
100–999	10	11	2	2	12	7
1,000–4,999	15	17	13	15	28	16
5,000–9,999	19	22	21	23	40	22
10,000+	24	27	54	60	78	44
Total	88		90		178	

C. Summary of the hookworm situation in Panama as compared with other parts of the world.

1. *Soil pollution and soil infestation with relation to sources of human infection.*

Climatic and soil factors apparently are quite favorable over most of the Republic of Panama for the dissemination of hookworm infestation during the long rainy season. It is probable that the higher level of the upland areas as compared with the coastal plains is due to a considerable extent to the greater rainfall, although the denser vegetation nearer the houses is probably the primary determining factor. This difference, however, is only relative since the worm burden of the coastal plains is of the heavy type which is usually considered to be of clinical importance. No evidence is available that differences in the kind of soil are important because the clay soil is covered in the shaded places by layers of humus which afford favorable culture conditions for the development of hookworm larvae. With climatic factors favorable over such wide areas the amount of

hookworm would be determined by the method of life and personal habits of the people.

To produce a high level of hookworm infestation such as that practically everywhere present in rural Panama, habits are necessary which make possible widespread intense soil infestation and considerable contact of the people with such infestation. No particular occupational relations were found which brought certain groups into more dangerous situations than others similar to those of the coffee pickers of Porto Rico (Cort, Riley and Payne, 1923). With general environment favorable for the development of the hookworm larvae for so much of the year and a universal absence of shoes in the ordinary activities of daily life, the hookworm infection of these people is apparently almost entirely due to habits of soil pollution, which produce concentrated or widespread areas of soil infestation in the vicinity of their houses. The seeking day after day of protected places for defecation would build up soil infestation which in certain places might produce from this activity alone most if not all the infestation of the individual or the group. Thus in places of limited cover not commonly visited for other purposes almost all the danger of contact with infected soil might come from daily visits for the purpose of defecation. In most cases, however, our surveys showed that the areas of soil pollution and soil infestation are not so limited. When the stools are spread widely in grassy places or are scattered in shaded places near the houses, wider and wider areas of soil infestation would develop during the course of the rainy season in the vicinities of the houses, and it would become increasingly difficult for both children and adults to avoid contact with infective larvae in the ordinary activities of the daily routine.

The studies on soil pollution outlined above for the different places surveyed in Panama illustrate a number of different types of pollution spots or areas. Where trees and shrubs were few and often at considerable distances as at many of the houses in Chorrerita, El Coco and Cocle, the stools both of children and adults were often deposited without any relation to cover. In some cases convenient hillsides or gulleys served, where conditions for development of the larvae were unfavorable. More often wide grassy areas were polluted, where the loosening of the soil and protection by the grass made possible the development of larvae often in abundance. In some areas (Marica Arriba) open grassy glades were chosen in preference and visited constantly for defecation in spite of an abundance of favorable cover. Where cover was distant often the children and perhaps occasionally

the adults would deposit their stools in the open near the houses, but some at least visited the shaded areas which were sometimes as far as 200 to 300 yards from the houses. The adults almost everywhere had some sanitary sense since they almost never deposited their stools in the yards and all the children except the youngest were taught to go outside the yard. Pollution by young children in the dooryards and close to the back of the houses was frequently found especially in the towns, but seemed to be more important in spreading ascaris and trichuris than in disseminating hookworms (see Section VIII and Brown, 1927). A habit which gave women and children some protection was the rather common use of chambers which were almost always emptied at places where there would be little chance for infection. Concentration of the pollution to very limited places, making a type of sanitation which was called in the Cacao groves of Trinidad the "natural latrine" (Cort and Payne, 1922*b*) was found in a few places but was rather rare. The commonest habit was the rather widespread pollution in the shade of the groves and thickets available near the houses. In such places as near certain locations in Marica Arriba and La Soledad the houses were partly or wholly surrounded by trees and thickets so that many shaded protected places were within easy reach. Under such conditions stools would be widely scattered and pollution areas frequently shifted so that the houses would become more and more encircled with soil infestation as the rainy season progressed. The conditions at La Soledad and around some of the houses in Marica Arriba are examples of situations of this type, which probably account both for the general high level of infestation at these places, and the extraordinarily heavy individual cases which were so frequent. Such situations are comparable to those found in Porto Rico (Cort, Riley and Payne, 1923) around houses in the midst of coffee groves.

As more and more epidemiologic studies are carried out on hookworm disease in various parts of the world the clearer it becomes that the daily pollution of soil in the environs of the houses is in the great majority of places the outstanding sources of infection. Exceptions to this are found in China (Cort, Grant and Stoll, 1926) where human excrement is returned to the soil as fertilizer and in Porto Rico (Cort, Payne and Riley, 1923) and Brazil (Smillie, 1922) where the soil of the coffee groves is widely polluted by the pickers. Chandler (1928), for example, feels that the act of defecation itself which takes the individual to an infested spot usually not otherwise visited is the primary factor in spreading hookworm in India. In the southern

United States the areas behind the barns used in lieu of latrines are considered very important sources of infection. With minor variations the same situation seems to hold throughout the broad hookworm belt of tropical America, where in the great majority of cases it has been found to be in the environs of the house rather than in the fields at a distance that the danger lurks. In Malaya, Siam, the East Indies, Egypt and almost everywhere that habits of soil pollution have been observed the same situation holds, making hookworm disease appear more and more to be a problem of household sanitation. As more and more information of this type accumulates the campaign for a latrine for each family comes each year to rest on a sounder basis as the most important method of control.

2. *Summary of hookworm infestation in Panama as compared with that in different parts of the world.*

To judge the hookworm situation in Panama as a whole before the introduction of control work we now have available in addition to the large mass of incidence statistics discussed in the first section of this report the egg counts on selected population groups. We can also judge to some extent from the counts included in the next section for places influenced by control work, what the level must have been before the campaign. The most striking thing that can be gained from these statistics is an idea of the widespread high level of hookworm infestation, and the prevalence of severe clinical hookworm disease in this country before the introduction of the control work. Exceptions to this are to be found in the large cities of the Canal Zone, Panama and Colon, where as far as can be judged from the general sanitary situation, the conditions of life of the people and the low incidence of infection, hookworm disease is not a significant public health problem (see Section I). The merchant and professional population and the wealthier people of the towns and cities of the interior are apparently partially exempt from this general heavy infestation as can be judged by their manner of life and the few statistics we have concerning them. Considerable hookworm infestation and clinical disease are, however, present in even the larger cities and towns of the interior as shown by the high incidence in David and Chitre (see Section I) and the relatively heavy infestation found in part of the population of Santiago and Penonome even after a considerable amount of control work had been carried on (see Section V). Two further exceptions to the general high level of infestation are shown by the comparatively low incidence of hookworm in some of the early records from certain parts of the province of

Bocas del Toro (see Section I) and the situation among at least part of the San Blas Indians, in one group of whom the incidence of hookworm was found to be only 4.7 per cent. (Caldwell and Caldwell, 1927). These authors attribute this situation to the habit of these people of defecating at the edge of the sea, where the development of the hookworm larvae is inhibited by the action of the sea water.

As shown earlier in this section we have evidence of two general levels of hookworm infestation, which appear to be representative of the majority of rural population of Panama living on the Pacific littoral. The lower of these two, representing the coastal plain where vegetation is sparse and the rainfall about 60 inches a year with an average egg count of around 10,000 eggs per c.c., is represented by the examinations from Chorrerita, Cocle and El Coco. The other level 50 per cent. higher, of well over 15,000 eggs per c.c. was found in the hills and the uplands where rainfall is greater and the vegetation much more abundant and is represented by the counts from Sardina and Marica Arriba and by those from La Soledad. The earlier incidence statistics and the comparisons of records of haemoglobin indices (see Section VII) from areas similar to these suggest that the conditions in all these places are not unusual but representative of the general situations in rural Panama, and that there are places where conditions are even worse. We feel, therefore, that the picture we have been able to give of these local situations is representative of rural Panama in general, and indicates a degree of hookworm infestation for a large proportion of the people of this country, which places it among the most heavily infested countries of the world. The chief factors which determine this situation, i.e., a long rainy season and intense soil infestation near the houses, have been discussed in some detail earlier in this section. Sufficient quantitative epidemiologic studies have not yet been made on hookworm disease throughout the world to make it worth while to try to make a world-wide comprehensive comparison of levels of hookworm infestation. We will, however, give a number of the estimates from recent studies in different parts of the world to see how the situation in Panama compares with those elsewhere. The most comprehensive recent discussions of this type are by Chandler (1928) and Rogers (1928).

We have been unable to find any figures which compare in size with the general population groups with those just analyzed from Panama.* Hill (1927) gives the counts from the village of Morovis

* Fülleborn, Dios and Zuccarini (1928) have published very recently the results of a series of egg counts made from people in the province of Corrientes in northern

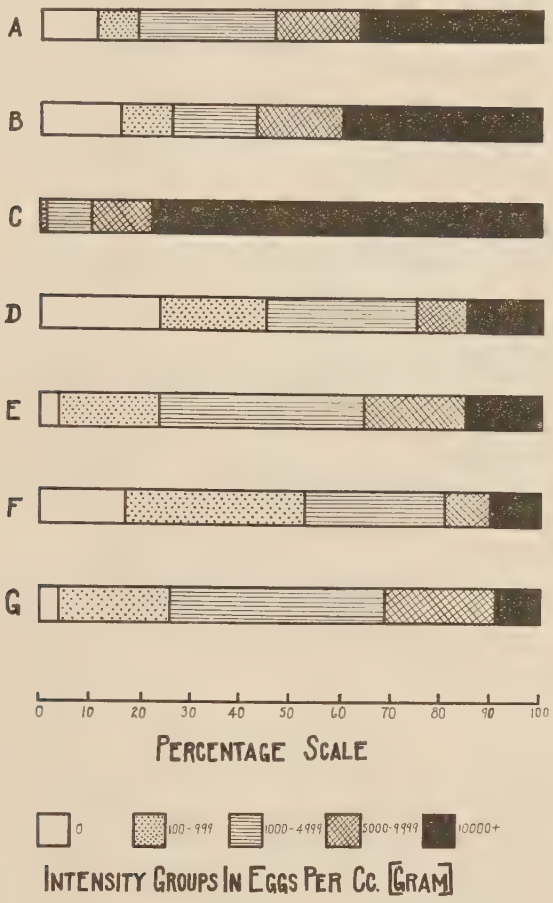
in central Porto Rico as representing the severest type of hookworm infestation in this island. His average count based on 510 cases is 8,270 eggs per gram or only about half as large as the highest averages from our Panama work.* The most heavily infested group of those studied by the China Hookworm Commission (Cort, Grant, Stoll, and Tseng, 1926) had an average egg count for 770 people of 4,692 eggs per gram. A very extensive series of studies in which the egg counting method was used has recently been completed by Chandler in India. He concludes (Chandler, 1928) that in spite of a high incidence of hookworm infestation, hookworm disease is practically non-existent in most places, and limited to a relatively small percentage of the population even in the most severely infested places. The index of infestation which he uses (see Chandler, 1926) shows only a few localities (some places in Burma and on some Darjeeling and Dooara tea estates) with an index exceeding 400. Elsewhere the indices are mostly below 200. Chandler compares these with an index approaching 600 for "Area C" in Porto Rico (Payne, Cort and Riley, 1923) and of over 500 in some rural school children in southern Alabama (Smillie and Augustine, 1925). The average egg count in the heaviest infestated region of Burma, which is limited to a very small zone, reaches 2,760 eggs per gram estimated on the basis of formed stools, which is considerably less than half as great as the average of our most lightly infested group from Panama where control work had been carried on (see Section VI). Applying Chandler's index to our two types of infestations the index for the coastal plains area (Chorrerita, El Coco and Cocle) is found to be 884 and that for the uplands (Sardina, Marica Arriba and La Soledad) 1,155.

The size of the egg counts in Panama as compared with other regions of the world where studies have been made is also shown graphically in a series of bar diagrams (Graph 4). Here the large

Argentine. These counts come closer to the size of those from Panama than any of those listed with the possible exception of the Porto Rican series. For example in the Argentine series the age group from 11–20 has an average egg count of 6885 eggs per gram basis mushy stool. It is interesting that this series differs from others from tropical America in that females of all age groups are more heavily infested than males and that the children and young people are more heavily infested than the adults.

* As indicated in Section III the figures from Porto Rico are not directly comparable with those from Panama on account of differences in stool size. If the averages for the Panama and Porto Rico stools in the series studied, which for formed stools were 100 and 150 grams respectively, hold in general for these countries the heaviest counts for Porto Rico would approach much more nearly those of our Panama series.

number of cases in the group of 10,000 eggs per c.c. and over in Panama as compared with the other series is very striking. When we consider these comparisons we wonder that the symptoms of clinical hookworm disease are not even more apparent in Panama. Some discussion of



GRAPH 4. Bar diagrams comparing the infestation of the Panama groups with certain groups from the literature. *A*. Coastal plains group (Chorrerita, El Coco and Cocle), males and females, all ages. (390 cases.) *B*. Sardina and Marica Arriba, females, all ages. (100 cases.) *C*. Sardina, Marica Arriba and La Soledad, males, 15 years and over. (122 cases.) *D*. Area of mulberry cultivation near Soochow, China, females, all ages. (359 cases.) (Cort, Grant, Stoll and Tseng, 1926.) *E*. Area "C" Porto Rico, males and females, all ages. (192 cases.) (Payne, Cort and Riley, 1923.) *F*. West African adult males. (137 cases.) (Gordon, 1925.) *G*. Mexican group, males and females, all ages. (555 cases.) (Carr, 1926.)

the effect on the population of Panama of their heavy worm burden with especial reference to the haemoglobin indices will be given in Section VII.

Two other points on which it will be of interest to compare our series with certain of those found elsewhere are the relative infestations of the males and females and the rapidity of the acquisition of the infestation in the children. In the series of egg counts from Panama the average infestation of the adult males is almost uniformly considerably greater than for the females. In the upland groups (Sardina, Marica Arriba and La Soledad) this difference is present also in the children. Two possible differences in habit have been already suggested for this heavier infestation in adult males. The only explanation we can suggest for heavier infestation in boys than girls is greater activity which would cause them earlier to use the pollution spots of the adults which would bring them more frequently than the girls into contact with infested spots. Heavier infestations in males than in females have been often found in various studies. This relation was true in all but one of the groups Hill (1927) lists from Porto Rico. In the earlier series of egg counts from this island, infestations as heavy or heavier in the females were found in two areas, one in which the pollution near the houses was very gross and another in which the women were engaged in coffee picking (Cort, Payne and Riley, 1923 and Cort, Riley and Payne, 1923). Carr (1926) found a lower infestation in females in all age groups in his egg count series from Mexico. Chandler (1928) finds in India but little difference between men and women in defecation habits, and his figures show approximately the same infestation in the sexes. In the China studies there were shown to be a considerable variation between different districts in this respect. Where the women had bound feet or where they did not share the work in the field they would have much lower averages as in the Chefoo area (Grant, Cort and Kwei, 1926) or in the Wuchang region (Stoll, Wassell and Kwei, 1926). Where they shared the work of the men and did not bind the feet their infestations were as heavy as those of the men as in the areas of cotton cultivation (Grant, Cort and Tseng, 1926) or in those of mulberry cultivation (Cort, Grant, Stoll and Tseng, 1926 and Cort, Oldt, Cadbury and Jeu, 1926). In fact in the Soochow mulberry area the infestation of the women from 11 to 30 years was very much heavier than that of the men (Cort, Grant, Stoll and Tseng, 1926, text fig. 2) apparently because the girls and young women were particularly active in the picking of the mulberry leaves, which gave the greatest exposure to infection. These

examples indicate some of the differences in activity between men and women which may be significant in modifying the comparative intensity of the infestation in the sexes.

A consideration of the average infestations of the early age groups for our Panama series shows several interesting things. Cases of surprisingly heavy infestation have been found in very young children, in which even a very liberal reduction for the small size of stools would still leave very heavy cases. In some of these, as in a child of less than a year in El Coco with an egg count of 29,800, there would be suspicion of mixing of tins in collecting samples. It would hardly be possible to explain the high average in the very young children in La Soledad in this way since it is brought to this level by five comparatively heavy cases in children two years old with the following counts: (1) 2,400, (2) 5,000, (3) 6,300, (4) 7,800 and (5) 17,800. In fact the size of the infestations in young children in this area is perfectly extraordinary since the 5 to 7 year group has an average equal to the adults, and in the 3 to 4 year group there are six cases between 5,000 and 10,000 eggs per c.c. and one with 22,700 and another with 38,700. This unusual situation in La Soledad in respect to the size of infestations in the children might be attributed to the dense cover near the houses. In the other groups from Panama the infestations in the children are less but still large, although except in La Soledad it is in about the same ratio to adult infestation as in a number of other places. It is interesting to note that our curves showing the acquisition of infestation for Chorrerita, El Coco and Cocle and for Sardina and Marica Arriba (cf. Graphs 2 and 3) are strikingly like those made in the Porto Rican studies (Payne, Cort and Riley, 1923, fig. 4 and Hill, 1923, Graph II) and Smillie's (1922, p. 15) findings for Brazil. This rate of acquisition may be considered as typical of situations where the infection comes chiefly from soil infestation in the vicinity of the houses. Where work in the field is the chief factor the infection may come in much later, as in the mulberry areas of China (Cort, Grant, Stoll and Tseng, 1926, Table II). The present situation in many parts of the southern United States as illustrated particularly by Alabama offers a unique situation in the relation of the infestations in children and adults, since the peak comes about the 15th year rising rapidly from about the 6th year and declining rapidly until after 20 years the number of worms is on the average negligible (Smillie and Augustine, 1925, Chart 4). This decline is attributed to the wearing of shoes by the adults. Enough has been given to illustrate some of the factors influencing the rate of acquisition of

infection in children, and to emphasize the intensity of the hookworm in the Panama children as compared with other parts of the world from which quantitative data are available.

The findings brought out in this section show why it has been so difficult to bring hookworm under control in Panama and help to explain why even after the extensive treatment and sanitary work the level is as high as it is shown to be in some of the areas discussed in Section VI.

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VI. A STUDY OF THE EFFECT OF TREATMENT AND SANITATION ON THE LEVEL OF HOOKWORM INFESTATION IN CERTAIN AREAS IN PANAMA.

By

W. C. SWEET, W. W. CORT, LOUIS SCHAPIRO, N. R. STOLL and W. A. RILEY.

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A. Introduction.

The development in the last few years of quantitative methods for measuring the degree of hookworm infestation makes it possible to obtain from intensive studies of areas where control measures have been applied valuable information on the effect either of the control work as a whole or of certain phases of the campaign procedure. Selected groups of people studied before, during the course of, and after the completion of control work, as by Hill (1925; 1926) in Porto Rico, yield the most definite information and such studies should be made as often as possible. Information of value can also be gained, however, by the examination of situations where the history of the control procedure is known even if they were not studied before the campaign began. This is especially true if there are available comparable places in the same region, untouched by treatment or sanitation which can be used to represent in a general way the original situation in the investigated areas. It is along these lines that we proceeded in our investigations in Panama in the summer of 1926. The groups analyzed in Section V of this report give the comparable unaltered areas. Since the places chosen for study had variable histories of control work, the series includes illustrations both from the coastal plain and the upland regions of the effect of treatment in non-sanitated areas and of the influence on the level of hookworm infestation of sanitation and treatment together. A description of these places is given in Section I and will not be repeated except in so far as the information will aid specifically in a clearer understanding of a local situation. The method of treatment and character of the sanitary program discussed in Section I of this report apply specifically to the areas under consideration here. In justice to the work of the Department of Uncinariasis in Panama, it is only fair to state that the places included in this study are not representative of the control methods employed in their most effective and recent form and can not be taken as illustrations of the effectiveness of the control program as it is being applied in Panama at the present time. They were in fact the first areas where sanitary work was undertaken after it was made possible by governmental decree.

B. The effect of treatment in unsanitated areas.

1. *General discussion.*

In the course of the hookworm control campaign in the Republic of Panama especially in the early years as was also the case in many other places, treatments were given to groups of people where it was

not feasible to get them to build latrines. In some of these unsanitated groups a considerable proportion of the population was treated and in others only a small part, since in many cases the people went for treatment to dispensaries at a distance from their homes. Such treated individuals would usually return to houses, where others in the families were untreated and where soil pollution went on unchecked. There were still other places where sanitation was not established for one, two or even three years after the treatment campaign. It is now the general opinion gained from widespread experiences that treatment without sanitation is of little permanent value in reducing hookworm infestation unless practically all of a population group is given a thorough course of treatment and there is no considerable influx of infested individuals from the outside. Such a course of treatment, given during the dry season when soil infestation had died out, would undoubtedly give the best results. The expulsion of so many worms and eggs following treatment during the wet season would of itself produce a temporary increase of soil infestation. The return of infestation in places where treatments were given without sanitation has only in a few instances been measured quantitatively, so that it is of interest to record our results in situations of this type in Panama. Studies were made on three groups with this history representing both the coastal plains and the upland types of infestation. Unfortunately these groups are all alike in that a considerable proportion of the people in each case were untreated, so that we have nothing to offer on the effect of mass treatment when almost all of a population group is treated.

2. *Comparison of treated and untreated individuals in El Coco.*

In Section V the untreated individuals examined from El Coco, Chorrerita and Cocle were combined and their infestation analyzed as representative of the situation for rural communities of the coastal plains region. From the village of El Coco the records show that 82 individuals had been given treatment for hookworms, of whom 79 had been treated in 1922 and the other three had been given one treatment each in 1920, 1925 and 1926 respectively. Of the 1922 series 18 had been treated once, 33 twice, 24 three times and 4 four times. Since the houses in El Coco are widely scattered, the contact between the different families is rather casual and each household probably represents practically a separate unit as far as hookworm dissemination is concerned. It is, therefore, important for our present comparison to know whether whole families had been treated or whether treated

individuals were in households containing untreated members. Only two of the families had all the members listed as treated and in four others the only untreated members were children under 10 years of age at the time of our survey. The other 27 families considered included both treated and untreated adults. Most of these people, therefore, had been exposed immediately after treatment not only to soil infestation coming from their own soil pollution but also to that coming from untreated adults. In view of the conditions of soil pollution and soil infestation in El Coco described in the last section, a rapid reinfection starting immediately after treatment was to be expected. We were surprised, therefore, to find any effect of the treatments whatever after four years.

Table 1 gives a comparison of the average egg counts of the treated and untreated individuals from El Coco ten years of age or over. This shows that even after exposure to constant reinfection over a period of about four years the treated group still had a level of infestation only about two thirds of the original level as judged by the average of the people living under the same conditions who had not received treatment.

TABLE 1.

A comparison of the treated and untreated persons in unsanitated areas in Panama, given as eggs per c.c. basis formed feces. (Only age groups of 10 years and over are included.)

Groups considered.	Treated.		Untreated.	
	Number of persons.	Average egg count per c.c.	Number of persons.	Average egg count per c.c.
El Coco, males	24	14,970	28	21,700
El Coco, females	36	8,460	18	12,310
Sardina, males	9	20,440	31	29,800
Sardina, females	10	15,650	17	21,110
Marica Arriba, males	14	15,480	12	18,970
Marica Arriba, females	12	14,530	14	13,490
Unsanitated part of La Atalaya, males	15	19,860	10	14,570
Unsanitated part of La Atalaya, females	23	13,960	25	12,450
La Soledad, males	57	23,810	15	24,940
La Soledad, females	34	15,600	16	9,900

3. *Comparison of the treated and untreated individuals in Sardina and Marica Arriba.*

Twenty two persons from the village of Sardina were recorded as previously treated for hookworm diseases. Of these 21 had been treated in 1922 and one in 1923. Sixteen had been treated three times, two four and three only once. In no instances had whole families been treated, so that in all cases treated and untreated had been living in the same houses. Since Sardina had been sanitated at the end of 1925, these treated individuals had been exposed for about three years to conditions very favorable for reinfection. It is interesting that the 40 year old man who was discussed in the previous section as the heaviest case ever recorded by an egg counting method (208,400 eggs per c.c.) was in the treated series from Sardina. His inclusion entirely obscures any differences that might be present in the rest of the group since it would raise the average for the treated group considerably above the untreated. He is, therefore, left out of the series. He can not, however, be entirely excluded from the picture, since we have no reason to doubt the record of his treatment. The averages (Table 1) with this case excluded are definitely higher in both males and females for the untreated groups, although the number of cases especially the treated is entirely too small to give any certainty that the differences are valid, especially in the light of the exclusion of the heaviest case from the treated group.

From Marica Arriba there were available records of treatment for 26 individuals who were also treated in 1922. Of this group four had been treated once, eleven twice, ten three times and one four times. In every case except for one house the treated individuals belonged to the same families as untreated adults. The average egg count of the five treated persons from this house was 6,800 eggs per c.c. which is only about one third of that of the rest of the treated group. Since this house is at a considerable distance from any of the others, these people were probably exposed only to their own pollution spots and thus saved from rapid reinfection by their treatments. Since Marica Arriba was unsanitated at the time of our survey the exposure to reinfection had been a little longer here than in Sardina. The averages of the treated and untreated individuals which are given in Table 1 show that no significant effect of the treatments was apparent after about four years, except possibly for the single family mentioned above.

4. *Comparison of treated and untreated individuals for La Soledad and the unsanitated part of La Atalaya.*

In La Atalaya 98 individuals of our series lived in houses without latrines, which were at quite a distance from each other and from the main part of the village around the square. The treatments dated back to 1918 and 1919. The comparison of the egg counts of the treated individuals with the untreated (Table 1) gives no evidence of any effect remaining at the time of our survey. In fact in this series as well as that from La Soledad the treated group has a higher average.

In La Soledad dispensaries were held in the latter part of 1919 and 1920, where a total of 77 individuals were treated. Later treatments were voluntarily sought in Santiago City. Our records show 104 listed as having been treated. In twenty-three families all those who were ten years of age or over in 1926 were in the treated series making a total of 75. This advantage was probably offset, however, in La Soledad by the fact that the houses were fairly close together and there was a constant intermingling of the people, in some cases more than one family using the same pollution areas. The averages shown in Table 1 give no evidence of any effect of the treatments remaining in this village. It is not at all surprising that these upland areas, in contrast with El Coco, did not show any effect of the earlier treatments. In the first place the interval after treatment was longer and in a place like La Soledad the conditions for hookworm dissemination are very favorable.

C. Comparisons in groups influenced both by treatment and sanitation.

1. *Effectiveness of latrine building in reducing soil pollution.*

Not the presence of latrines in a community but the degree to which they are used is the criterion of the effectiveness of the sanitary part of the hookworm control program. In Panama it has been found that not only is it necessary to have latrines built, but by constant inspection to insist that they are kept up and used. Even with a well organized inspection system it is of course not to be expected that sanitation will be perfect. The soil pollution studies of the sanitated places included in our surveys give some interesting information on the effect of latrine building and inspection on the soil pollution habits of the people, and give some indication of the way in which the sanitary program in Panama is holding up. We will, therefore, give the details of our soil pollution studies in the places considered in this section as an introduction to the analysis of the egg

counts. Although the egg counts from Sardina are not included here since the level of infestation had only been under the influence of the sanitation for about six months, the results of the survey for soil pollution made in this place will be discussed as an example of the immediate effect of latrine construction on the soil pollution habits of the people in a rural village.

The work of latrine construction in Sardina was undertaken in 1925 and latrines at a majority of the houses had been completed in November or December of that year. Four of them had just been finished at the time of our visit and at one place the latrine was still under construction. Before this time the only latrine in this village which was built in 1922 was at the school. Universal soil pollution had been the rule and under conditions very favorable for the development of soil infestation an extremely high level of hookworm infestation had been built up (see Section V). A careful survey was made of this village on July 16, 1926 with certain later check-ups. The results of this survey gives an idea of the extent to which the introduction of latrines affected the soil pollution habits of the people of this village. At the time of our survey 22 of the houses in Sardina were occupied, of which 4 were without latrines. Two of these were merely small annexes to larger houses, and in both places it was claimed that the latrines of the main houses, which were not far away, were used. At one of the other houses a good latrine was in process of construction so in reality only one house at which only two old people lived showed no attempt at sanitation. There were, therefore, twenty of the houses and the school which were provided with latrines at the time of our survey. The school latrine, as far as we could discover by questioning and observation, was used by the pupils and no signs of soil pollution were found in or near the school yard. At twelve houses the people claimed that the latrines were always used and we were unable to find any evidences of soil pollution. All the others except one were in partial use, most of the soil pollution found being attributed to the children. At the house where the latrine was unused there lived two adults and six children ranging in age from 7 to 19, who spread their stools widely among the clumps of bushes near the house and further away in shaded situations. At another house a situation of interest was found since it was claimed that all the family used the latrine except the mother and the grandfather 85 years of age each of whom had their particular pollution spot to which they had made paths in the grove across the road from the house. It will be seen from the record just given that the sanitation

in Sardina was quite effective representing a very great improvement over the previous situation as represented by the conditions of soil pollution in Marica Arriba. Whether after such a start the situation would improve or become worse would depend on the efficiency of the inspection service. Presanitation of such effectiveness as this lays the basis for treatment which will give lasting benefit. One point that should be noted further is that the people of Sardina were probably very well prepared for the introduction of latrines, since a number of them had been sufficiently interested in the hookworm campaign to ask for treatment, and all of them were undoubtedly more or less familiar with the sanitary and educational work that had been carried on in Penonome since 1922. The situation here in the use of latrines is quite encouraging and is probably about what can be expected in any community in Panama into which sanitation is introduced under the present conditions of information about and interest in the work of the Department of Uncinariasis.

2. *A discussion of the situation in the village of La Atalaya.*

a. General considerations.

A general description of the Santiago district and the village of La Atalaya has been given in Section I of this record. With the heavy rainfall and the abundance of vegetation near the houses the favorableness of the environment for the development of hookworm larvae in the soil is comparable to that at Marica Arriba and La Soledad (see Section V). This and the high averages in the unsanitated parts of the village indicate that there must have been originally a high level of hookworm infestation. The economic condition at La Atalaya was much better there than at La Soledad, and some of the people around the central square were engaged in occupations other than agriculture, such as baking, storekeeping, etc. It is probable, therefore, that the precampaign level here was somewhat lower than that for La Soledad. The first sanitary work was done in La Atalaya in 1919 although little if any use was made of the latrines then constructed and they were torn down the same year. Reconstruction was started in 1921 and sanitary inspection had been carried on since that time, so that this date should be considered as that of the real introduction of sanitation. The majority of treatments were given in La Atalaya in 1919 although a number date back to 1918. This means that most of the treatments were given two to three years before the sanitation was introduced.

Earlier in this section a comparison was made between the treated

and untreated individuals living in the unsanitated houses of La Atalaya. This gave no evidence that the effects of the earlier treatments still persisted. Here we will compare the treated individuals with the untreated from the houses having latrines in use, and those living under conditions of soil pollution with those who used the latrines. To make these comparisons understandable it will first be necessary to discuss the results of our soil pollution and soil infestation survey.

b. Soil pollution and soil infestation studies.

The village of La Atalaya consists of a part bordering the central square and the outlying houses (see Map V of Section 1). The houses around the central square although surrounded by an abundance of vegetation represent more of the urban type of community and some families living in them not engaged in agricultural work. On the other hand the outlying houses are considerably scattered and are strictly of the rural type. Only two of the 25 houses around the central square were found at the time of our visit to be without latrines and at three others soil pollution was found comparable to that at the houses unprovided with latrines. At eleven of the other houses no trace of pollution was found, while at the nine others there were only scattered stools apparently from the children. It is evident in view of the favorable environmental conditions that even such scattered pollution would be a constant source of infection. Two situations of particular interest were found in the central square itself. There was no latrine for the boys' school and the pupils were accustomed to deposit stools along the sides of the street near the school. Also visitors from the surrounding districts and perhaps some of the inhabitants themselves deposited stools along certain of the streets. These locations were undoubtedly sources of some infection. Since the girls' school had a latrine it is of interest to compare the average infestation of the pupils of these two schools. The average of 49 boys 6 to 14 years of age examined from the boys' school was 8,400 eggs per c.c. and that of the 41 girls of the same age group examined from the girls' school was 7,200. It is not of course possible to be certain that this difference can be attributed to the presence of a latrine at the girls' school since so many outside factors would operate in both groups and after all the difference is hardly significant.

While this survey showed that in most of the houses around the square latrines were present and in use, it was found that the conditions of soil pollution and soil infestation in the outlying houses were comparable to those in La Soledad. This situation has been

described in Section V where it was shown that very gross soil pollution and heavy soil infestation were present in this part of La Atalaya.

c. Influence of sanitation and treatment on the intensity of hookworm infestation at La Atalaya.

In the comparison which will be made between the sanitated and unsanitated groups in La Atalaya we include in the unsanitated group those living in houses without latrines, those in which the latrines were unused at the time of our survey and those who had had latrines less than a year. Comparisons made without relation to previous treatment showed that the average infestation of the people in the sanitated group was lower for both the males and females and in the young children, the school children and the adults (see Table 2).

TABLE 2.

Comparison of the average egg counts of the sanitated and unsanitated groups in La Atalaya.

Sex.	Age group.	Sanitated or unsanitated.	No. of cases.	Average egg count per c.c.	Average corrected according to standard population.
Males....	0–4	Sanitated	10	2,210	
		Unsanitated	8	3,410	
	5–14	Sanitated	25	10,170	
		Unsanitated	13	12,450	
	15+	Sanitated	30	12,350	
		Unsanitated	17	20,750	
	Total	Sanitated	65	9,950	10,040
		Unsanitated	38	14,260	15,570
Females..	0–4	Sanitated	7	710	
		Unsanitated	5	6,880	
	5–14	Sanitated	20	8,300	
		Unsanitated	16	9,490	
	15+	Sanitated	38	5,940	
		Unsanitated	39	13,320	
	Total	Sanitated	65	5,100	5,700
		Unsanitated	60	11,760	10,280

It is possible that part of this difference might be due to the better economic condition of part of those in the sanitated group and to the fact that some of this group were engaged in non-agricultural pursuits. This can hardly be considered the determining factor, however, since when such people were without latrines they were exposed on account of the conditions of soil and vegetation to the soil infestation near their homes of the same type as that affecting the rest of the people in the village. It is interesting to note (Table 2) that except for the females in the 0–4 age group, in which the number of cases is very small, the differences are very much greater in the adults than in the children. In the light of our surveys this suggests that the children in the sanitated houses were still visiting pollution spots and not deriving the same protection as the adults from the presence of the latrines.

In La Atalaya we have records of 98 people 10 years of age or over at the time of our survey who had been treated in 1918 and 1919. A comparison of these with the 58 individuals of the same age group who had not been treated is given in Table 3. A comparison between the treated and untreated individuals living under unsanitated conditions has already been made but is repeated in Table 3 for the sake of convenience in comparison. It can be seen that in the treated females who lived in sanitated houses the average egg count is considerably less than in those who had not received treatment. In all the other cases (Table 3) the treated individuals had a somewhat

TABLE 3.

Comparison of the treated with the untreated in the sanitated and unsanitated houses of La Atalaya.

(Only individuals ten years of age and over at the time of our survey are included.)

	Males.		Females.	
	Number.	Average egg count.	Number.	Average egg count.
Sanitated: Treated.....	27	15,160	33	5,780
Untreated.....	11	9,320	12	8,530
Unsanitated: Treated.....	15	19,860	23	13,960
Untreated.....	10	14,570	25	12,450

higher average than the untreated. While the numbers in these groups are very small it is possible that the lower average egg count of

treated females in the sanitated houses is really significant, since it is evident that sanitation would ordinarily influence the females more than the males since they are more restricted to the houses. The effect of the treatments given seven or eight years before was apparently eliminated except possibly in the females in the sanitated houses. Considering the other variable in Table 3 our survey shows that 83 individuals living in sanitated houses had an average egg count of 9,700 eggs per c.c. and 73 living in unsanitated houses had a count of 13,340 (see also Table 11 for a similar situation in Rio Grande).

d. Analysis of the group as a whole.

For certain comparisons it will be necessary to give a brief analysis of the egg counts from the village of La Atalaya taken as a whole, representing a situation of the upland region where by sanitation and treatment the level of infestation had been reduced to about that characteristic of the coastal plains. The census of this village was 269 and our egg count series included 227 individuals giving a good representation of the population. The corrected average egg count of the whole group was 10,040 per c.c., with the 103 males having a corrected average of 12,030 and the 124 females of 8,060.

TABLE 4.

Analysis of the egg counts of La Atalaya according to age and sex.

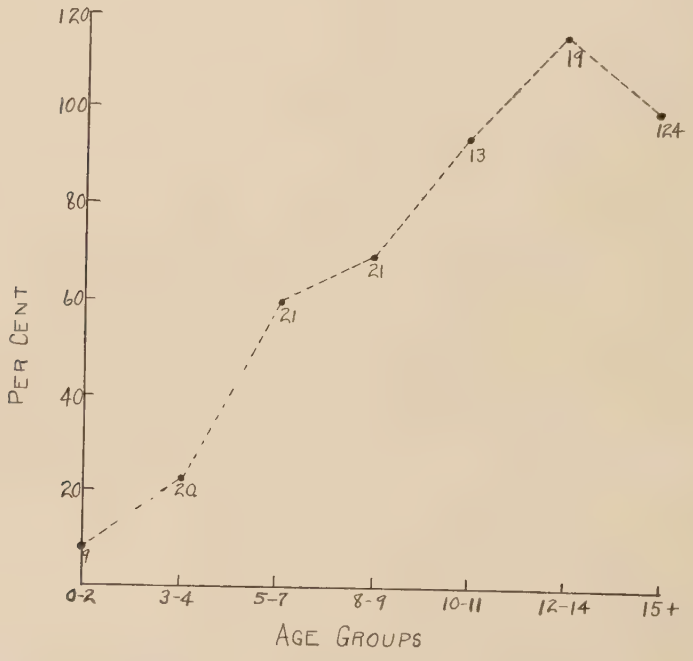
Age groups.	Males.		Females.	
	No. of cases.	Av. egg count per c.c.	No. of cases.	Av. egg count per c.c.
0–4	18	2,740	11	1,020
5–14	38	10,950	36	8,830
15+	47	15,390	77	9,680
Total	103	11,550	124	8,660
Corrected average		12,030		8,060

Table 4 gives the averages of the natural age groups, from which it can be seen that differences between the males and females are present in the average counts of the children as well as of the adults. The analysis into the intensity groups (Table 5) and according to the acquisition of infestation (Graph 1) makes possible direct com-

TABLE 5.

Analysis according to infestation groups of the egg counts from La Atalaya.

Intensity groups.	Males.						Females.					
	0–14		15+		Total.		0–14		15+		Total.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Negative.....	5	9	4	8	9	9	7	14	5	7	12	10
1–999.....	7	12	6	13	13	13	9	19	9	11	18	14
1,000–4,999.....	16	29	6	13	22	21	13	27	22	29	35	28
5,000–9,999.....	14	25	7	15	21	20	8	17	16	21	24	19
10,000+.....	14	25	24	51	38	37	11	23	25	32	36	29
Total.....	56		47		103		48		77		125	



GRAPH 1. A representation of the rate of acquisition of infection in the children examined from La Atalaya. The average egg count for each age group is given as a percentage of the adult average (15 years and over). One case in the 0–2 group of 28,200 eggs per c.c. is omitted since it probably represents a substitution of specimens.

parisons with other Panama groups.* Table 6 gives the cases from this village with egg counts of 40,000 eggs per c.c. or over. They are not quite as numerous as in some of the other groups and are equally distributed between the sexes.

TABLE 6.

List of cases from La Atalaya with egg counts of more than 40,000 eggs per c.c.

Males.		Females.	
Age.	Count.	Age.	Count.
14	61,600	9	44,000
17	41,900	15	80,000
30	49,200	16	42,000
45	57,000	26	46,400
75	73,600	55	41,000

It is of interest to compare the egg counts from La Atalaya with those of La Soledad in some of the points shown in the analysis. It is doubtful for reasons given above whether the original level of infestation for La Atalaya was as high as for La Soledad. We can, however, assume that the hookworm campaign, especially the sanitation, had reduced the level at La Atalaya from one approaching that of La Soledad (cf. Section V, Table 8 with Table 4 of this section). The comparison of these two series shows that the average of the 0 to 4 group in La Atalaya was very much lower than at La Soledad. Also the school children in La Soledad had a considerably higher proportional infestation as compared with the adults. This suggests that even the degree of sanitation in La Atalaya was particularly effective in keeping down the infestation in the children, under general environmental conditions quite similar to those which produced the extraordinarily high infestations in the children of La Soledad. This situation is made even clearer by a comparison of the rate of acquisition of infestation in the two places (cf. Section V, Graph 3 with Section VI, Graph 1), in which it is shown that up to 10 years of age the infestation is much more slowly acquired in La Atalaya. It is also of interest that the differences between the average infestation of the males and

* Here and elsewhere in this section where the egg counts of children are given, the discussion of the size of the children's stools in relation to their egg counts should be kept in mind (see Sections III and V). The counts for the children are directly comparable all through this series, but it seems certain that the counts as given exaggerate their infestations when compared with adults.

females are considerably greater in La Soledad than in La Atalaya. Another difference which is very striking is that the percentage of cases of 10,000 eggs per c.c. is much less in La Atalaya than at La Soledad, indicating that at the first place the conditions are considerably less favorable for the building up of severe clinical cases (cf. Section V, Table 9 and Section VI, Table 5). This probably accounts in part at least for the higher average hemoglobin index in La Atalaya as compared with La Soledad.

It is perhaps of interest to compare the infestation of La Atalaya with that of the coastal plains group (Chorrerita, El Coco and Cocle). While the latter group has a slightly higher average infestation there is a great similarity in the distribution into the age groups, the differences between males and females, the rate of acquisition especially up to ten years of age, and the distribution into the intensity groups. It may perhaps be postulated that the artificial conditions limiting hookworm dissemination produced by the introduction of latrines have much the same general effect in La Atalaya as the natural conditions of less rainfall and less available cover in the other area. It may also be significant that these somewhat adverse conditions cause a slower acquisition of infestation in each group, and tend to prevent the building up of so many extremely heavy cases.

3. *Analysis of a group from certain of the poorer sections of Santiago City.*

a. General discussion of the situation.

The fecal samples examined from Santiago City were obtained from two of the poorer sections of the town, most of the people being of about the same economic status as those of La Soledad. Undernourishment was, therefore, very common. About 40 per cent. of the men worked occasionally at least as agricultural laborers on the farms away from the town. As elsewhere in this region the population showed a predominance of white blood.

The hookworm campaign began in Santiago in 1919. All except a very few of the latrines had been built in 1920 and 1921. About two thirds of the people ten years of age or over at the time of our survey had been treated in 1920 and 1921 and the scattered records of later treatments show the effect of the dispensary which was kept up in the city. The chief points, therefore, of our Santiago study are to get a measure of the effect of treatments after a period of years in a community with a fair degree of sanitation and to get some idea of the conditions in the towns of the upland region.

b. Soil pollution and soil infestation studies.

During our study of this area we made on August 12, 1926, an inspection trip visiting in all 43 houses which included most of those from which the samples for examination were obtained. The regular inspectors reported that in the business section of the city and the better residence districts the latrines were generally used and kept in reasonably good condition. Thirty two of the houses that we visited had latrines of the type which passed the inspection of the Department of Uncinariasis. In four of the other houses the people used latrines of the houses next door; in six they used chambers which were emptied into covered pits in the back yards; and in only one place was there no provision whatever. The yards were very small, and the houses so close together that in most places pollution spots outside the yards were not available. The soil pollution, therefore, which was found was almost always within the yards near the houses and often back of or to the sides of the latrines. In 27 of the 43 houses no evidence of soil pollution could be discovered, and in 10 of the remaining houses the people insisted that all the adults used the latrines and that the traces of stools found came from the children. In fact in only eight yards was there any considerable evidence of soil pollution and at only three places were the conditions at all comparable to those in unsanitated areas. The yards were densely shaded and the soil was in most cases quite loose or covered with vegetation and wet from the heavy rains. Every indication was that the conditions in the yards themselves were very favorable for the development of hookworm larvae. From 15 yards where traces of stools were found 27 soil samples were taken. Eleven were positive yielding numbers of infective hookworm larvae varying from 16 to 1,600. At only five of the houses did the numbers of larvae recovered constitute a heavy soil infestation. No more potentially dangerous situation than these yards has been encountered and evidently the depositing of only a comparatively small number of eggs might yield numbers of larvae, which on account of the narrow confines of the yard would have a particularly good chance of infecting the inhabitants.

c. Effect of sanitation and treatment in Santiago.

As noted above there were only five houses included in our survey at which conditions of soil pollution were found at all comparable to those in an unsanitated area. It is of interest to note that the 10 children between one and ten years of age examined from these houses had an average count of 15,560 eggs per c.c. and that three of these

children had very heavy infestations, i.e., a 7 year old boy with a count of 50,200, a 10 year old boy with a count of 30,600 and a 9 year old girl with a count of 25,200. These severe cases are easy to explain when we consider that the areas of soil infestation are in the yards where the children would be in constant danger of contact with them. This makes it seem very probable that the children of this group must have been very heavily infested before the introduction of latrines in 1920 and 1921. The bearing of this situation on infection with ascaris and trichuris will be discussed in Section VIII.

In 1920 and 1921 at about the same time as the building of the latrines about two thirds of those recorded in the 1926 census as 10 years of age or over had received treatment. There were available in our egg count series 48 individuals of this age group who had not received treatments and 97 who had been treated. As seen in Table 7

TABLE 7.

Comparison of the treated and untreated individuals 10 years of age and over for the series examined for Santiago.

	Males.		Females.	
	No. in group.	Av. egg count.	No. in group.	Av. egg count.
Treated.....	21	16,190	76	8,080
Untreated.....	15	17,850	33	12,070

the number of males in this series is small making the slight difference in them of doubtful significance. In the females, however, the untreated have a much higher average egg count than the treated. Since the females would be less exposed than the males to outside sources of infection and appear to be cleaner in their habits this difference seems easy to explain and the figures for the females may probably be interpreted as expressing the effects of the earlier treatments. Since the treatments were given at about the same time that the latrines were introduced, it is not at all surprising that their effects were more lasting than under the conditions prevailing at either La Soledad or La Atalaya.

d. Certain points of interest in the analysis of the Santiago group as a whole.

The group of 232 examinations from Santiago is rather unbalanced since it was difficult to get the men to submit samples. Taking into consideration the distribution according to age and sex the corrected

figure for the average egg count of this group is 11,210 eggs per c.c. Table 8 shows the average infestation according to the natural age

TABLE 8.

Analysis of egg counts from the Santiago group according to age and sex.

Age groups.	Males.		Females.	
	No. of cases.	Av. egg count.	No. of cases.	Av. egg count.
0–4	24	3,480	16	1,180
5–14	39	10,540	41	6,610
15+	22	20,850	89	9,710
Total	85	11,220	146	8,110
Corrected average		14,810		7,600

groups and sex. The corrected averages give an infestation for the males almost twice as high as for the females. This difference is present both in the children and in the adults. It can possibly be explained here as elsewhere by greater activity in men and boys which exposes them more and more to sources of infection away from the house, the women and girls to a greater extent being protected by the sanitation of the houses. As noted above about 40 per cent. of the men work as agricultural laborers in the rural districts. This situation is in line with the finding given above that the effects of treatment in the females still persisted after almost six years. On the

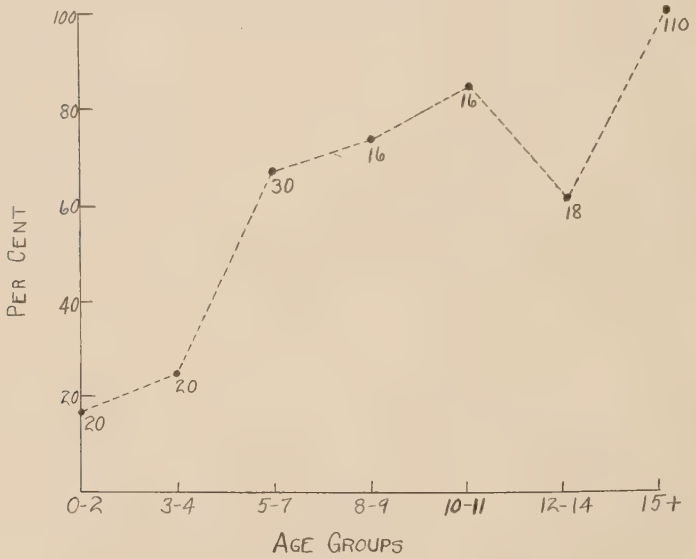
TABLE 9.

Analysis according to infestation groups of the egg counts from Santiago.

Intensity groups.	Males.						Females.					
	0–14		15+		Total.		0–14		15+		Total.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Negative	11	17			11	13	17	29	9	10	26	18
1–999	9	15	1	4	10	12	8	14	11	12	19	13
1,000–4,999	12	19	9	41	21	25	16	28	25	28	41	28
5,000–9,999	11	17	3	14	14	16	8	14	22	25	30	20
10,000+	20	32	9	41	29	34	9	15	22	25	31	21
Total	63		22		85		58		89		147	

other hand when the situation in some of the yards in Santiago is considered it is possible that the men obtain most of their infection at home and cleaner habits produce the differences in the women.

Table 9 and Graph 2 give intensity groups and acquisition of



GRAPH 2. A representation of the rate of acquisition of infection in the children examined from Santiago. The average egg count in each age group is given as a percentage of the adult average (15 years and over).

infestation analyses which make this series directly comparable with those previously discussed. Finally Table 10 lists the cases over 40,000 eggs per c.c.

TABLE 10.

List of cases from Santiago with egg counts of more than 40,000 eggs per c.c.

Males.		Females.	
Age.	Count.	Age.	Count.
7.....	50,200	22.....	141,600
17.....	105,400	47.....	45,800
36.....	56,800	51.....	43,700
52.....	104,000		

The fact that after over six years of control work, in which the sanitation had developed until practically all of the houses had

latrines pretty generally in use, the level of infestation in the Santiago group was still higher than that of La Atalaya, and about that of the coastal plains group, indicates a high previous level and conditions potentially very favorable for hookworm dissemination. Since the males 15 years of age and over are comparatively so few in number and it is probable that some of them were exposed to infection in their work away from home, it seems probable that the women and the children under 15 years more accurately picture the situation in these poorer sections of the town itself. It is interesting to compare these groups with those examined from La Atalaya village. The only significant difference between the women and children of these two places is in the 5 to 14 group of the females which have a somewhat higher average infestation in La Atalaya than in Santiago (cf. Table 4 and Table 8). All our evidence indicates that the amount of soil pollution in the Santiago area taken as a whole was very much less than for La Atalaya, and comparisons between the treated and untreated groups in both places also show greater differences in Santiago. This seems to emphasize the point made above of the relatively greater danger of a comparatively small amount of pollution in the narrow confines of the yards in Santiago where conditions for the development of the larvae are as favorable as in any place visited in Panama and where the danger of contact with infested soil should be so greatly increased. This danger is also clearly brought out by the extremely heavy ascaris and trichuris infestations found in the Santiago group (see Section VIII). This danger is also shown by the rate of acquisition of the infection up to 10 years of age in Santiago which is more rapid than in any group studied in Panama with the exception of La Soledad. It seems probable from these facts that the original level of infestation in Santiago was very high especially in the children and that it may have approached that of La Soledad. This is of especial interest since it illustrates a situation where conditions within a town of considerable size may be as favorable for the dissemination of hookworms as in the country districts of the same region.

It is also of interest to compare the Santiago situation with that of the coastal plains group (Chorrerita, El Coco and Cocle) which had not been influenced by treatment or sanitation. The average infestation in the two groups is about the same. The adult females have a considerably higher infestation in the coastal plains group than in the Santiago series. On the other hand the average for children under 10 in the Santiago group (6,040 eggs per c.c.) is somewhat greater than in the coastal plains group (5,200 eggs per c.c.) in spite

of the extensive sanitation in the first place, and the rate of acquisition of infection is very much more rapid in Santiago (cf. Section V, Graph 2 and Section VI, Graph 2). It appears from these comparisons that any considerable further reduction of the level of infestation in Santiago City will require extensive treatment and even more carefully checked sanitary inspection.

4. *Analysis of the egg counts from Penonome, Rio Grande and Garicin in relation to the influence of treatment and sanitation.*

a. Character of sanitation and treatment in these areas.

A description of the town of Penonome and the villages of Rio Grande and Garicin has been given in Section I. These places are all partially sanitated and a considerable proportion of their population had been treated so that an analysis of the groups examined gives information of the effect of treatments and sanitation on the urban and rural population of the coastal plains region.

Sanitation and effective treatment in Penonome date from 1922 when latrines were built at about 75 per cent. of the houses and about 35 per cent. of the people were treated. Some further dispensary treatments have been given since that time and the sanitation has been improved until in 1926 the report of the sanitary inspector showed 90 per cent. of the houses with latrines in use. Our own inspection of 61 houses on two streets showed that all but 5 had latrines, the great majority of which were constantly used. In Penonome as elsewhere in Panama it may be practically taken for granted that the majority of the young children especially those of pre-school age do not use the latrines even where the adults are very conscientious in their use. The percentage of children using the latrines appeared to be higher in Penonome than in either Rio Grande or Garicin. It did not require much search, however, even in Penonome particularly in the outskirts of the town to find stools in considerable numbers in the paths or elsewhere near the houses. The people in Penonome, even the children, wore shoes to a much greater extent than in any of the rural districts. A large number of fecal examinations were made from Penonome which will be analyzed in the light of the conditions described. Since people were constantly moving in from rural districts we have eliminated those in our series who had been residents less than three years on the ground that their infestations would represent to too great an extent the conditions under which they had formerly lived. Even this would not entirely remove the effect on the level of infestation of the influx of people

from rural districts such as Sardina, Marica Arriba and La Pintada. As our central laboratory was located in Penonome a considerable number of fecal samples were brought in for examination by people, who wanted to know whether they needed hookworm treatment or not. This group was originally listed separately under the heading of "voluntary" series. To make our examinations from Penonome more representative we solicited specimens from the people living on two streets extending the length and breadth of the town which gave us a series of 197 examinations from 61 different houses. We feel that these two series taken together give us a good sampling of the people in this town.

From the 88 houses in Rio Grande 218 examinations were made representing 50 houses. In a careful inspection of a random sample consisting of 39 of these houses it was found that 35 or about 90 per cent. were provided with latrines, most of which had been built in 1923 and which had been included in the sanitary inspection service since that time. From personal observation it was possible to divide the latrines into two groups, (1) those apparently used by at least part of the household and (2) those which seemed to be used only rarely or not at all. Statements of the people on the use of the latrines were often worthless, one family insisting that their latrine was in daily use, when it had been found packed with barbed wire. Of 34 houses with latrines those in 25 were classified as in use and 9 as not in use. In practically all cases the young children did not use the latrines. Soil samples were taken from pollution spots near 13 houses in Rio Grande. Thirteen were found to be positive with numbers of infective hookworm larvae ranging from one to as high as 800 or 900 per sample.

All the houses in Garicin, 52 in number, were visited and samples were obtained from 144 persons living in 38 houses. Twenty-eight of these houses were inspected personally and 23 were found to have latrines most of which were built in 1925. Seventeen of these latrines were apparently in use by at least some of the family. Seven out of 12 soil samples taken from pollution spots near 10 houses were found to be positive with numbers of larvae ranging up to 1,000 per sample.

Rio Grande and Garicin are situated on a plain where trees or other cover which might be used for defecation spots are rare. Whenever cover was available within reasonable distances of the houses it was usually used but in most cases where soil pollution was found the stools were widely scattered on the open plain, often in grassy places. With only two exceptions the stools, except those of the very youngest

children, were deposited outside the yards, some of the favorite defecation spots being at extraordinarily long distances from the houses. Usually the stools were widely scattered instead of being concentrated in definite spots. As shown in the last section wherever the stools were scattered in grassy places there would be the possibility of the development of soil infestation, which would account in part for the infestations of the people. There was practically no wearing of shoes, at least on ordinary occasions by any of the people of Rio Grande or Garicin.

b. A comparison of a sanitated with an unsanitated group in Rio Grande.

The number of people in Penonome, Rio Grande and Garicin living in houses without latrines is so small that only one small group of "unsanitated" people is available for comparison. These people lived in houses in Rio Grande which had no latrines or where a considerable amount of soil pollution was found. They are compared with the group in the same village, where the latrines were used and soil pollution was not found. Since the houses in Rio Grande are very much scattered it seems very probable that most of the worm burdens of the people especially of the women and children would be acquired

TABLE 11.

Comparison of the average infestation of sanitated and unsanitated groups in Rio Grande.

(Males 15 years of age and over not included.)

Age group.	Latrines used.		Latrines not present or unused.	
	No. of cases.	Av. egg count per c.c.	No. of cases.	Av. egg count per c.c.
0–4	8	1,370	7	5,560
5–9	13	1,510	8	3,030
10–19	15	1,850	8	4,450
20+	20	3,950	7	14,060
All ages	56	2,450	30	6,570
Average corrected for age		2,720		8,980

from the vicinity of their own houses from the soil pollution habits of the family itself. Since some of the men worked away from home and might be exposed to infection in other places the group used in

this comparison includes all the females and the males under 15 years of age. This comparison is made in Table 11. It will be seen that the group living under unsanitary conditions showed a much higher average egg count in every age group. The effects of previous treatments do not influence this difference since the percentage of treated was higher in each age group among those living in unsanitated houses. Although these groups are too small to be used for definite conclusions of any general scope it seems very probable that the lower average of the sanitated group was due to the latrines which had been built at these houses in 1923.

c. The effect of hookworm treatment.

The records of the Department of Uncinariasis give the names of those who had received treatments in Penonome, Rio Grande and Garicin in the campaign conducted in 1922. There are also records of scattered treatments given from the dispensary in Penonome since that time. In the comparison of the average infestation of treated and untreated individuals the examinations from Penonome will be considered as an urban area for comparison with a rural group including those from Rio Grande and Garicin. Only people living in houses having latrines are included in this comparison.

Certain statements in regard to the influence of particularly heavy cases on the averages in Table 12 need to be given. In the first place

TABLE 12.

A comparison of the average egg counts of the treated and untreated groups from Penonome, Rio Grande and Garicin.

Sex and age.	Rural area.				Urban area.			
	Treated.		Untreated.		Treated.		Untreated.	
	No. ex.	Av. egg count per c.c.	No. ex.	Av. egg count per c.c.	No. ex.	Av. egg count per c.c.	No. ex.	Av. egg count per c.c.
Males, all ages	49	7,610	90	6,750	46	5,870	82	10,970
Average corrected for age		9,410		8,090		6,120		13,990
Females, all ages	45	2,730	128	6,670	74	4,800	98	4,500
Average corrected for age		3,290		8,030		4,620		5,040
Average of both sexes corrected for age and sex		6,350		8,060		5,370		9,010

two cases with egg counts over 40,000 eggs per c.c. greatly influence

the average of the treated males in the rural area. With those two cases removed this average falls from 9,410 to 6,560, which is well below the average of 8,090 for the untreated males of this area which included no such heavily infested cases. In the same way the average of the untreated males in the urban area is raised very greatly by four heavy cases three of which have a count of over 100,000 eggs per c.c. which clearly is not characteristic of town infestation. With these cases removed the untreated males in the urban area have a corrected average of 7,110 eggs per c.c. which is still somewhat higher than that of the treated, but which seems more in the general picture of the Penonome situation. In the same way the removal of one case with 146,400 eggs per c.c. from the untreated females of the rural area changes the corrected average from 8,030 to 5,490, which however is still very much higher than the average of the treated. This influence of the heavy cases and the small size of the groups make it necessary to draw conclusions cautiously from such comparisons as those in Table 12. This comparison suggests that the females of the rural areas are more protected against new infections. This is to be expected since soil pollution is widespread in the rural areas, while in the urban communities it is concentrated about the houses.

TABLE 13.

Hookworm intensity groups for Penonome, Rio Grande and Garicin as effected by treatment and sanitation.

(Both sexes 10 years of age and over.)

Intensity group.	Rural area.				Urban area.			
	Treated.		Untreated.		Treated.		Untreated.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Negative	5	7	6	5	18	20	15	15
100–999	20	28	16	13	18	20	10	10
1,000–4,999	24	33	36	29	28	30	31	31
5,000–9,999	6	8	28	23	13	14	18	18
10,000+	17	24	37	30	15	16	25	25
Total	72		123		92		99	

The figures either as they stand or with the heaviest cases removed when summed up for males and females seem to indicate that the

effect of the treatments still persisted in these groups. They show also a considerably greater difference between the treated and untreated in the urban area than in the rural. This is what would be expected, theoretically, since in the urban area (Penonome) the latrines were built at about the same time as the treatments were given, while Rio Grande was not sanitated for more than a year after treatment and Garicin for almost 3 years, giving a chance for more rapid reinfection. Further the sanitation appears to be better in Penonome than in the rural areas.

The analysis of the treated and untreated series into intensity groups (Table 13) gives further evidence on the effect of treatment. Here the sexes are considered together and only those 10 years of age and over are included. In both the urban and rural areas a larger percentage of the individuals fall into the heaviest two egg count groups in the untreated as compared to the treated series and a larger percentage of negatives occur in the treated group.

d. Analysis of total egg counts for Penonome, Rio Grande and Garicin.

From Penonome, Rio Grande and Garicin the egg counts of 835 individuals are available for combined analysis excluding a small group from Penonome who had not been in residence three years. These counts belong to four series, Penonome "Voluntary," Penonome "Survey," Rio Grande and Garicin. These are set up separately in Table 14 but elsewhere the two Penonome groups are placed together as an urban or town series and the two village groups are combined as a rural series. These groups are of interest in representing the level of hookworm infestation in communities of the coastal plains of Panama, where a considerable amount of hookworm control work had been carried out. They represent levels of hookworm infestation reduced from the original situations by both treatment and sanitation and which were at the time of our study under the influence of a degree of sanitation probably about equal to the average conditions achieved in other areas in Panama where the sanitary campaign had been carried out and which were under the supervision of sanitary inspectors. Certain points of interest can be brought out by comparing these groups with each other and with others of our series. We have, therefore, given them much the same analysis that has been used for the other groups of this section and Section V (see Tables 14, 15, 16 and Graphs 3 and 4).

In comparing the average infestation in the groups (Table 14) it is seen that Rio Grande is considerably lower than Garicin. This is

TABLE 14.

Average egg count per c.c. in residents of Penonome, Rio Grande and Garicin.

Males.

Age group.	Rio Grande.		Garicin.		Rural area. Rio Grande and Garicin.		Penonome.						Grand total.	
							Voluntary.		Regular survey.		Total town area.			
	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.	No.	Av.
0–4	20	1,630	12	450	32	1,180	27	730	18	70	45	460	77	760
5–14	34	2,590	17	5,620	51	3,600	61	10,350	35	10,670	96	10,470	147	8,808
15+	37	9,410	40	13,340	77	11,450	43	9,360	33	20,020	76	13,990	153	12,710
All ages	91	5,150	69	9,200	160	6,890	131	8,040	86	12,040	217	9,620	337	8,470
Corrected average		6,250		9,070		7,590		8,170		14,110		10,750		9,440
Females.														
0–4	25	3,800	17	820	42	2,600	22	760	14	170	36	530	78	1,640
5–14	33	6,040	16	3,210	49	5,110	61	3,480	38	6,310	99	4,560	148	4,740
15+	62	5,330	41	10,380	103	7,340	70	5,700	59	10,240	129	7,770	232	7,580
All ages	120	5,210	74	6,630	194	5,750	153	4,100	111	7,620	264	5,580	458	5,650
Corrected average		5,260		6,990		6,000		4,330		7,590		5,770		5,890

probably due to a smaller reduction from the original level in Garicin since in this place the latrines were not built until almost three years after the treatments, while in Rio Grande only about one year separated the treatments from the sanitary work.

The difference in the averages between the "voluntary" and "survey" group in Penonome is partly due to the larger number of heavy cases in the second series. Another probable explanation would be the larger proportion of the better classes of the town included in the voluntary group as compared with the survey group. Taken together we consider that these two groups give a pretty good cross section of the town of Penonome and in all the further analyses they will be considered together.

The corrected average for the Penonome series is considerably higher than for the rural area (Rio Grande plus Garicin). This is quite surprising when we compare the control history and present sanitary conditions which except for the percentage treated are all in favor of the town group. This difference is entirely due, however,

TABLE 15.

Analysis into intensity groups.

A. Rio Grande and Garicin.

Intensity groups.	Males.						Females.					
	0–14		15+		Total.		0–14		15+		Total.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Negative	28	34	1	1	29	18	33	36	7	7	40	20
100–999	16	19	7	9	23	14	26	29	24	23	50	26
1,000–4,999	22	27	20	26	42	26	21	23	29	28	50	26
5,000–9,999	11	13	17	22	28	18	5	5	18	18	23	12
10,000+	6	7	32	42	38	24	6	7	25	24	31	16
Total	83		77		160		91		103		194	

B. Penonome.

Negative	46	33	14	18	60	28	53	39	27	21	80	30
100–999	16	11	8	11	24	11	23	17	21	16	44	17
1,000–4,999	30	21	23	30	53	24	31	23	40	31	71	27
5,000–9,999	21	15	9	12	30	14	13	10	16	13	29	11
10,000+	28	20	22	29	50	23	15	11	25	19	40	15
Total	141		76		217		135		129		264	

to a heavier infestation of the males since in the two series the average for the females is about the same. Part of this difference is produced by the presence of a larger number of heavy cases in the males of the town group (Table 15). It is probable that the males of Penonome go away to work to a greater extent than those of Rio Grande and Garicin who have in many cases plots for cultivation at home and are also busy with the care of cattle in their immediate neighborhood. We may perhaps, therefore, consider the very high average infestation of the men and older boys in our Penonome series as representing situations away from home, often in the hills where the conditions for hookworm dissemination are very favorable. Even with the males excluded the high level of infestation in Penonome as compared with the rural group is surprising. It suggests that there must have been a surprisingly high level for Penonome before the control work started. Unfortunately there is not available in our series any comparable town of the coastal plain where the original level is uninfluenced by control work. It seems quite probable, however, that the original level of Penonome was even higher than that of the rural coastal plain region as represented by Chorrerita, El Coco and Cocle. It is probable also that before the building of latrines the crowding in Penonome made soil pollution in the yards very common. A suggestion of the danger of pollution of this type comes out of the discussion given above of Santiago where there is also a surprisingly high level of infestation in spite of fairly satisfactory sanitation. We can feel fairly certain, therefore, that the conditions for the spread of hookworms were as favorable if not more favorable in Penonome before the introduction of latrines as in the unsanitated rural areas of the coastal plain. This situation is stressed because it indicates a situation in Panama somewhat different from most countries, since in this country urban conditions of certain types are in no way a safeguard against hookworm infection. It must not be forgotten, however, that the constant influx of large numbers of people from such rural districts as La Pintada, Marica Arriba and Sardina which have the higher upland type of infestation, as well as the visits of the men to rural districts would tend to bring in constantly heavily infested people, which would tend to keep the level high both under unsanitary conditions and after the building of the latrines.

Fortunately we have available in our coastal plains group (Chorrerita, El Coco and Cocle) which was discussed in the previous section, a situation fairly comparable with our rural area where control work had been carried out and it is probable that this group represents

fairly closely the original level of infestation which was present in Rio Grande and Garicin. Cocle especially is valuable for comparison because it is practically continuous with Rio Grande and Garicin. Cocle, however, was peculiar in the character of the pollution spots, many of which were gulleys which served as "natural latrines." The use of such spots may have served to keep down the level of infestation in this place, since whatever soil infestation developed in them would not be easily accessible to the people visiting them. The corrected average for the 390 untreated individuals for Chorrerita, El Coco and Cocle is 11,650 eggs per c.c. and that for Cocle is 9,790. The differences between these averages and that for Rio Grande and Garicin (6,790 eggs per c.c.) can probably be attributed to the reduction which has been brought about by the control campaign. While this reduction seems rather small when the amount of work done is considered, it indicates definite progress and makes further reduction by keeping up the sanitation and by retreatment seem entirely feasible. It must not be forgotten in this connection that only about half the people in these two places were treated and that the building of latrines followed the treatments. It is in fact encouraging to find any results remaining after only partial control work of this type. What may probably be expected from the more recent type of control program in Panama, which includes presanitation followed by general treatment, can be gathered from the great reduction in mass infestation and slow reinfection that Hill (1926) found in his presanitated areas in Porto Rico.

It is further of interest to point out in this connection that the corrected average of 7,660 eggs per c.c. for the 835 individuals of the combined town and rural groups is extraordinarily high for communities where campaign work has been carried on. In fact this is a degree of infestation which is close to that of the most heavily infested areas, which have been studied by quantitative methods from other parts of the world (see Section V).* The high degree of infestation in this series is still further emphasized by the analysis into intensity groups shown in Table 15. The large number of cases in the two higher groups and especially in that with 10,000 eggs per c.c. or greater shows that the number of clinical cases present is still great. Such analyses show that in this and similar areas in Panama where partial control measures have been carried out the fight is still in its early stages,

* It should be again noted that the size of stools in Panama as judged by the series discussed in Section III is rather small as compared with those from Porto Rico. Such small size of stools tends to make the egg counts too large as compared with places where the average stool size is greater.

and that it will take the continuance and improvement of the sanitation by the constant vigilance of the sanitary inspectors and further general treatments to bring the level down to where the infestations are predominately of the subclinical type.

From Table 15 certain further comparisons of interest can be made. In the first place although the town group has a considerably larger proportion of negatives than the rural group, due probably to the inclusion of a larger number of people of the better classes, it has about the same percentages in the higher infestation groups indicating the presence of a considerable amount of hookworm disease. While a number of comparisons of considerable interest can be made from the intensity group analysis of this series with that of the other groups in this section and in Section V, we will make only one more between the rural group (Rio Grande and Garicin) and the coastal plains group of Section V (Chorrerita, El Coco and Cocle). If these two series are compared (cf. Section V, Table 3 and Table 15 of this section), it will be seen that the differences are chiefly in the first two and the last intensity groups. In other words in the series where the control work had been carried on the numbers in the negative and most lightly infested group had increased considerably, the two intermediate groups had remained about the same while the number in the highest group had considerably decreased. This probably means simply a reduction all along the line just as would be expected with a generally improved situation.

Tables 14 and 15 show except in the youngest age groups heavier infestations in males than in females. This probably reflects in addition to differences in habits which have been discussed elsewhere a greater influence on the women than on the men of the sanitation since the infestations of the females probably depend to a greater extent than those of the males on the conditions near the houses.

Throughout this whole area some of the men gave histories of leaving home at certain seasons of the year to work "in the fields." These journeys were usually undertaken in the rainy season and it seems probable that the conditions under which they lived away from home would be very conducive to hookworm infection. This habit might account for the greater number of extremely heavy cases among the men than among the women (Table 16). It is of interest in this connection that in the rural area the difference between the average infestation of the males and females is not nearly as great as in the Penonome group. It seems possible that journeys away from home are less common in the rural area than in Penonome, because in Rio

Grande and Garicin many of the people cultivated plots near their houses and also worked with the cattle that were pastured near the villages.

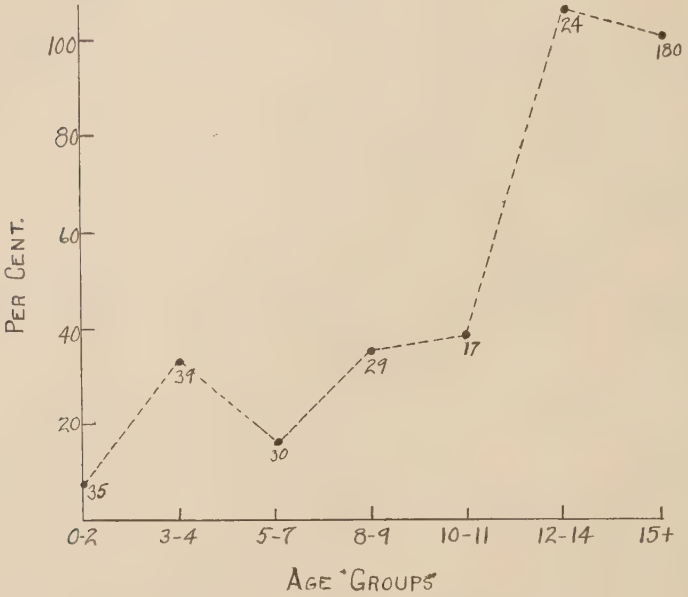
TABLE 16.

Cases over 40,000 eggs per c.c. in Rio Grande, Garicin and Penonome.

Males.		Females.	
Age group.	Count.	Age group.	Count.
Rio Grande:			
40–44	42,800	12–14	146,400
Garicin:			
20–24	59,200	18–19	46,200
30–34	47,600	55–59	54,700
50–54	49,800		
Penonome Survey:			
5–7	101,900	10–11	45,000
25–29	85,800	30–34	60,000
25–29	71,000	35–39	43,400
45–49	81,600	72	159,800
Penonome Voluntary:			
10–11	55,200	35–39	43,400
10–11	100,800	60	89,100
12–14	56,400		
12–14	46,300		
18–19	104,000		
30–34	56,000		
45–49	53,700		

That the sanitation of these areas tends to protect the young children is shown by a consideration of the averages for the 0–4 group in both the rural and town areas (Table 14) as compared with the coastal plains area (Chorrerita, El Coco and Cocle) (see SectionV). That this protection lasts up toward adult age is shown by the Graphs 3 and 4 which show a slower acquisition of infection than for any of the other areas which we studied in Panama. The very high percentage of the 3 to 4 year group in the rural area (Graph 3) is due to two extremely heavy cases, one of 32,600 eggs per c.c. and the other 31,100 eggs per c.c. All the other children of this age group are very low as compared with the area where control work had not been carried on. In the same way the high average of the 5 to 7 year group for Penonome is due to one case of 101,900 eggs per c.c. Without

this case which belongs in the heaviest dozen cases of our whole Panama series the average for this age group is very greatly reduced. It seems possible, therefore, to conclude that the sanitation in these



Graph 3. A representation of the rate of acquisition of infection in the children examined from Rio Grande and Garicin (rural area). The average egg count in each group is given as a percentage of the adult average (15 years and over).

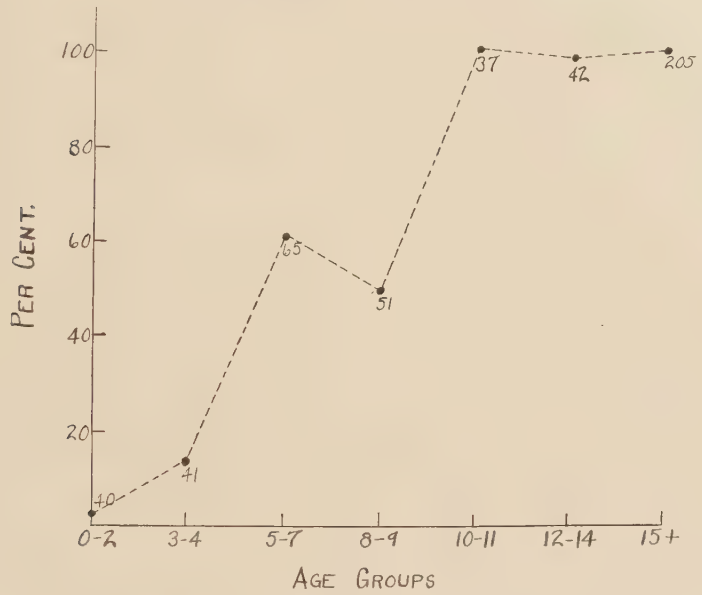
areas is fairly effective in keeping down the infestation of the younger children.

D. Discussion and conclusions.

1. *Quantitative information in the literature on the effect of hookworm control work.*

The experiences in hookworm control in the Saint Gotthard tunnel, the mines of Europe, of Ashford and his co-workers in Porto Rico and those of the Rockefeller Sanitary Commission in the Southern United States had by 1914 placed the foundations of the hookworm control program on a firm basis of practical experience. It was thought that the intensive application of the methods developed up to that time would make possible the eradication of hookworm infestation from any area. In all this early work human infestation was measured by the incidence of infection supplemented in some cases by physical examinations and tests of the degree of anemia by

hemoglobin determinations. It came as a great shock, therefore, to find in a number of places that the hookworm control work which had been carried on had reduced the incidence of infection but little or not at all below the percentage found in the preliminary examinations. These findings introduced a note of pessimism into much of



GRAPH 4. A representation of the rate of acquisition of infection in the children examined in Penonome. The average egg count in each age group is given as a percentage of the adult average (15 years and over).

the discussion at the beginning of the last decade. A great step in advance came when Darling and his co-workers in the Orient and Brazil (Darling, Barber and Hacker, 1920; Darling and Smillie, 1921; and Smillie, 1922) introduced the worm counting method for the quantitative measuring of hookworm infestation. Their work made it possible to evaluate control measures quantitatively and emphasized the fallacy of comparisons made on the basis of incidence alone, which fail to consider differences in the number of the worms in the individual cases. The later development of egg counting methods (Stoll, 1923, and Caldwell and Caldwell, 1926) has greatly increased the ease of making quantitative comparisons. The following quotation from the report of the International Health Board of the Rockefeller Foundation for 1925 is of interest in this connection: "The development of the Stoll dilution egg-count method of determining hookworm

intensity has revolutionized administrative procedures in the control of the disease." (Int. Health Board, 1927, p. 62.) Although it has taken some time for these newer ideas to become generally accepted there are already in the literature a number of studies in which the effect of hookworm control work has been measured by quantitative methods and the dilution egg-count method is becoming each year a more important part of both hookworm control work and field investigations.

Before summarizing the investigations which we have discussed in this paper we will mention briefly some of the more important attempts that have been made to evaluate the results of hookworm control campaigns by quantitative methods. One of the earliest attempts of this type was made by Smillie (1922). He showed by studies made on a population group in Brazil, that while a three year intensive hookworm campaign had hardly diminished at all the percentage of the people found positive for hookworms by fecal examination, hookworm disease had practically disappeared and the average number of worms per individual had been reduced to a low level. He concluded further that while treatment alone had greatly reduced the intensity of infestation, reinfection was taking place very rapidly in those people who had not installed latrines or who were not using them.

Another resurvey, also of interest in this connection, was made about the same time by Sisco (1923) in Antigua. Here the people studied had been thoroughly treated five years previously with thymol and the area had been partially sanitated. While he used only incidence statistics to measure the infestation the results were interpreted in the light of studies of the hemoglobin index. In his series the incidence in the resurvey was 21.2 per cent. as compared with the original figure of 29.8 per cent. Of especial interest was the fact that in 300 people who had been treated to a microscopical cure five years before, the incidence at the time of the resurvey was 16.3 per cent. Sisco interpreted his finding at the time of the resurvey of an equal hemoglobin rate in the positive and negative group to mean that the intensity of the infestation had been reduced by the control measures.

Information on the rise of the intensity of infestation after treatment was obtained by Sweet (1926) from the analysis of a series of 8,239 individuals in Ceylon who were examined by the Stoll method. The intensity of infestation in those of this group who had not been treated was comparatively low since the average of the untreated group was only 1,108 eggs per gram on the basis of mushy stools.

With this figure as the basis for comparison he was able to compare the averages of 2,686 individuals who had been treated at yearly intervals up to nine years before the date of the examinations. All these people were living under varying sanitary conditions, in which soil pollution was common. His findings indicated that the increase in the intensity of infestation was most rapid in the first three years after treatment after which a level was maintained up to about the seventh year. Then a slow rise approaching the original level was found for the eighth and ninth years. The incidence percentage also showed the same initial sharp rise for the first three years which shaded off more slowly to approach closely to the percentage incidence of the untreated.

Docherty (1926) discussed a somewhat similar series of egg counts also made from Ceylon. He concluded that "irrespective of the number of treatments given reinfestation proceeds steadily from the time of completed treatments." His figures showed that regardless of the number of treatments received 33 months before the average villager had reacquired a definite number of parasites representing 67.17 ± 0.97 per cent. of his untreated neighbors.

The best controlled series of studies of this type has been made by Hill (1925; 1926) in Porto Rico. He was able to compare the return of infestation in two groups of treated people one without any sanitation and the other with latrines built some time before treatment. Both groups were egg counted before the treatments. In one year after treatment the reinfection had raised the intensity to half that before treatment in the unsanitated area, while in the presanitated area half the people were positive but with an intensity only 12 per cent. of the original level. In this same presanitated area in which the latrines were generally used another resurvey three years after the treatments showed that the incidence of infection was now 58 per cent. but that the intensity of infestation was only 20 per cent. of its original level. The farmers showed the greatest absolute increase and the children under 10 years of age the greatest relative increase.

Stimulated by the quantitative point of view Sawyer (1925) published a theoretical consideration of the factors concerned in maintaining a "level of equilibrium" of human infestation and on the changes in this level following control measures. Among a number of interesting points he suggests that "with constant environmental conditions, the rate of increase of hookworms rises with decrease in the density of the hookworm 'population.'" He also expresses the view that reinfection would tend to be more rapid where the original level of equilibrium was high.

From these studies it can be seen that a beginning has been made on the quantitative study of the effect of control measures, and on the rate of the return of infestation after treatment alone or after treatment and sanitation. The return of infestation appears to be more rapid in the first one to three years and much more rapid in unsanitated than in sanitated groups. Differences in the original level of infestation also seem to effect the rate of return. The results of the studies we made on the effect of control measures in Panama add certain information of interest along these same lines. The sum total of the available information is still, however, very small and many more studies of this same type are needed under the differing conditions found in different parts of the world.

2. *Summary of the Panama studies on the effect of control work.*

The comparison of treated and untreated individuals living in unsanitated communities in Panama shows a rapid return to the level of infestation of the untreated group. A difficulty in interpreting these comparisons comes from the fact that we have little information on which to judge just how much reduction the treatments produced in the infestations of the treated individuals themselves or in the mass infestations of the communities as a whole. Certainly since only a part of the people in each of the groups considered were treated the levels of infestation could not have been reduced in any case as much as 50 per cent. The largest proportional treatment was in La Soledad where about three fourths of the people six years of age or over were treated, but even here a total 50 per cent. reduction would probably be a liberal estimate. With such a high level of infestation remaining after the treatment in unsanitated communities where soil pollution was so prevalent, it is no wonder that reinfection came about rapidly in the treated individuals. It can be seen that after about three years in Sardina and four years in Marica Arriba there is little if any difference left in the degree of infestation in the treated and untreated groups, with the possible exception of the single family in Marica Arriba all of whom had been treated and which had a much lower infestation than the rest of the village. In La Soledad after about 6 years and in the unsanitated part of La Atalaya after about 7 years no evidence whatever of the effect of treatments can be noted. In fact in these places the average infestations of the treated groups was at the time of our survey almost uniformly higher than the untreated. Only in El Coco did our comparisons show differences that might be interpreted as the effect of the previous treatments. Here

after about 4 years the treated group showed an average infestation only about two thirds that of the untreated. The isolation of the houses of this village might in certain cases have helped to conserve the effects of treatments. It is probable, too, that the fact that this village belongs to the coastal plains area, where in the last section we have shown the level of infestation to be less than two thirds that of the uplands region, was a determining factor in the slower reinfection. This fits in with the view expressed by Sawyer (1925) that beginning with lower "levels of equilibrium" the return to the original level will come about more slowly. When we consider the intensity of the infestation in such places as La Soledad and Marica Arriba with surroundings almost ideal for hookworm dissemination, it is no wonder that with no reduction of soil pollution the effect of partial treatment of the population had disappeared in three to four years. To us the striking thing was that in El Coco the treated still showed a considerably lower infestation after four years of exposure to infection under unsanitated conditions.

In contrast to this situation were the comparisons made between treated and untreated groups in places where there was a fair degree of sanitation. It is possible that the effect of the treatments still persisted after seven years in the females in La Atalaya, who lived in the houses which had latrines in use, since their average infestation was only about half that of all the females and about two thirds of that of the females from the same houses who were not treated (Table 3). This effect of treatment, if it can really be interpreted as such, is surprising since at La Atalaya the latrines were built about two years after the treatments were given. A more clear cut difference is present between the treated and untreated groups in Santiago, where treatments and the building of latrines had both come the same year, six to seven years before our survey. Here the treated females, who would be less subject than the males to infection away from home, had an average egg count of about one half that of the males and two thirds that of the untreated females living under similar conditions. The situation in the group examined from Santiago is also especially interesting in showing conditions in a town which are very favorable for hookworm dissemination. Here after over five years of control work the level of infestation is still remarkably high.

It is interesting to compare the situation in Penonome with that in Santiago since both are towns of considerable size, and one represents the coastal plains condition and the other the uplands. In Penonome also the treated had a considerably lower average infestation than the

untreated after four years, during which they had lived under fairly good sanitary conditions (Table 12). This difference is greater than that for Rio Grande and Garicin which had been sanitated about a year and almost three years respectively after the treatments had been given. Penonome also represents a surprisingly high level of infestation as compared with the rural areas of the same region. It seems probable that both Santiago and Penonome had before the control work average infestations as high or perhaps even higher than the comparable rural districts. This situation is probably due to favorable conditions in the yards for infection and is in line with what we know of the general high incidence of hookworm infection in the towns and cities of the interior of Panama (see Section I).

Comparisons of those living in houses in which latrines are used with those under unsanitary conditions were possible for three of the areas. In La Atalaya the males living in sanitated houses had about 70 per cent. as heavy infestations as those in the unsanitated and the females had only a little over 40 per cent. (Table 2). Part of this difference in the females could, however, be attributed to previous treatments. Also of interest in this connection is the group of 10 children mentioned above living under unsanitary conditions in Santiago who had an average infestation of 15,560 eggs per c.c. This suggests the extreme danger of soil pollution under the particular conditions in the yards of this town.

The series for Rio Grande (Table 11) gives the most striking illustration of the influence of sanitation since here the individuals living under the sanitary conditions had an average infestation only about 30 per cent. of that of the people living under unsanitary conditions. These results show that the introduction of latrines tends to conserve the effect of treatment and to reduce the level of infestation under all the types of conditions covered by our groups.

Unfortunately we have no studies from groups where control work had not been carried on directly comparable with those from Santiago and Penonome. In both these places all our evidence points to a considerable reduction in the infestation from surprisingly high levels. In La Atalaya also it is possible that the original degree of infestation was comparable to that of La Soledad and that a considerable reduction was produced by the control campaign. On the other hand it seems quite certain that the difference in average infestation between those examined from Rio Grande and Garicin and the average for the comparable Chorrerita-El Coco-Cocle group can be attributed to the control campaign. It is, therefore, encouraging

to find that in this group, which have been subjected to control work, the average is less than 60 per cent. of the group where no control work had been done.

Finally it must be noted that in spite of the evidences of the effect of the treatment and building of latrines the reduction of the levels of infestation in these various groups is comparatively rather small after a considerable amount of control work, and that there are still present large numbers of heavy cases. This seems to be unavoidable in the dispensary type of campaign in which with the best of cooperation usually less than 75 per cent. of a community is treated. In fact even in the groups of our series where the most extensive control work had been done the worm burdens are still comparable to those of the very heavily infested areas elsewhere in the world, where quantitative studies have been made. The favorableness of the environmental conditions for the development of hookworm larvae in the soil has made the control of hookworm disease in Panama a problem the difficulty of which the earlier workers had little conception, and instead of being almost accomplished after 13 years of work it is really only getting under way.

We need no further evidence after our studies and those reported by Hill (1925) of the ineffectiveness in a country of heavy hookworm infestation of treating a portion of a population without sanitation Such methods have long since been abandoned in well organized control programs. It is evident that except for its educational value, and temporary individual relief all the early work in Panama was without effect. It was only when sanitation became the keynote of the campaign that more lasting results were achieved. If our investigations can be interpreted as suggesting any change in the present methods, it would be in an even more intensive emphasis on sanitation before treatment and a greater development if possible of the sanitary inspector system. But perhaps more than anything else the finding of such heavy average infestations in areas where control work had been carried on suggest the need of repeating the treatment campaigns wherever sanitation has become effective. Intensive treatment campaigns in such places as Santiago, Penonome and Sardina where sanitation has reached a fairly high level, would probably produce more permanent good than anything else that could be done.

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VII. HEMOGLOBIN LEVELS IN PANAMA AS A MEASURE OF THE INTENSITY OF HOOKWORM INFESTATIONS.

By

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A. Introduction.

Anemia has always been considered the most constant single symptom of hookworm disease. One reason that it figures so largely in all clinical discussions of this disease is that it is the only symptom that can be measured quantitatively with any degree of accuracy and facility. It is not at all surprising, therefore, that hemoglobin indices, obtained by one or another of the various methods, are so widely used in estimating the effect of hookworms on individuals or groups of people. It is of course recognized and repeatedly stressed by authors who have considered this problem, that estimates of the severity of hookworm disease by anemia alone must be carefully qualified on account of other anemia-producing factors which may be present. Among these factors are malaria or other debilitating diseases and unfavorable environmental conditions such as overcrowding, over-

work or an insufficient or unbalanced diet. The conclusion of the Uncinariasis Commission of the Orient (Darling, Barber and Hacker, 1920) that irrespective of other anemia-producing conditions, the hemoglobin index can be used as a general measure of the severity of hookworm disease, has been generally accepted. Certain conditions which influence the resistance of individuals or population groups to the anemia-producing effects of hookworm infestation were discussed by this Commission and have been repeatedly noted by later observers. In the first place there is considerable evidence that the effect of a given number of worms is more pronounced in children than in adults. The question of racial immunity has also received attention. Stiles and others early observed that in the southern United States the negroes suffered less from hookworm disease than the whites. It was not clear at this time whether this difference was due to differing intensity of infestation or to differences in resistance to the effects of the worms present. Smillie and Augustine (1925) in studies made with the egg-counting method found in Alabama that when the two races were living under "almost identical conditions of sanitation, economic status, occupation, soil temperature, etc., the whites may have a heavy infestation whereas the negroes have a very light infestation." They reported further that while clinical hookworm disease is very common in the white children of southern Alabama they scarcely found a single case of hookworm infestation in a negro in Alabama severe enough to produce clinical symptoms. Knowlton (1919) had also earlier noted that the worm counts of negroes from the Carolinas and Florida were only about a fourth of those of the whites. These observations suggest a racial resistance to the establishment of hookworm infestation, which is a very different thing from a resistance to the production of anemia from worms present. Gordon on the other hand (1925) in a study of the health of 137 West African natives has shown that even in hookworm cases with egg counts ranging from 11,200 to 124,000 eggs per gram, no effects could be demonstrated on the hemoglobin percentage, the general fitness or mentality. These results are interpreted as indicating a racial resistance to the effect of hookworm infestations in the negro race. With the present quantitative methods of measuring the intensity of hookworm infestation these studies with those reported in this paper open up a very important field for future investigation on racial differences both in the facility of the establishment of hookworm infestation and the resistance to the presence of the worms.

The general nutrition of an individual or a group has also been

shown to produce a profound effect on the resistance to the effect of hookworms. Smillie (1922) showed that a group of milkers on an estate in Brazil who were well nourished on account of drinking an abundance of milk had a hemoglobin average far above that for individuals of the same age group and living on the same estate who harbored a comparable number of hookworms, but who were distinctly undernourished. The experience of field workers in general is in agreement that well nourished adults can often harbor very heavy infestations of hookworms without having a reduced hemoglobin or any noticeable clinical symptoms.

In spite of these factors which may cause confusion in the use of the hemoglobin index as a measure of the severity of hookworm disease it is still pretty well demonstrated that in most population groups anemia is in a general way related to the intensity of the hookworm infestation. In the last few years there has been an attempt to determine whether a definite relation could be established between the degree of the anemia and the number of worms present. The studies of the Uncinariasis Commission to the Orient (Darling, Barber, and Hacker, 1920) demonstrated a definite negative correlation in certain groups between the number of worms harbored, as determined by the worm count, and the hemoglobin index as determined by the Dare method. Later Stoll and Tseng (1925) and Stoll, Tseng and Li (1926) found a negative correlation just as valid between the size of the egg counts and the hemoglobin index determined by the Talquist scale in two groups of Chinese. Similar results were also obtained by Carr (1926, Chart 1) in a group of 555 cases belonging to the laboring classes in Mexico. Smillie and Augustine (1926) show a significant reduction in the average hemoglobins in the heavier infestation groups in their series.

With the status of the relation of hookworm infestation to anemia such as has been indicated in the brief review given above, it has seemed worth while to bring together in this section of the report the information that is available from our studies on the hemoglobin of different groups in Panama. There is first available a large number of hemoglobin determinations which have been included in the reports of directors of the Department of Uncinariasis in Panama. These determinations were made by the Talquist scale by well-trained sanitary inspectors whose estimates were carefully checked from time to time by medical officers in charge. Since egg counts were not made on these same individuals their hemoglobins cannot be used for comparison with different degrees of infestation. They give, however,

a considerable amount of information on hemoglobin averages in different parts of Panama and show in certain instances the effect of the treatment campaign on the anemia.

We have also available from the studies made in the summer of 1926 a considerable series of hemoglobin determinations on individuals from our egg count series. These were made by two different sanitary inspectors who had had long experience with the use of the Talquist scale. One of them, who made the determinations in our series from the Penonome district was checked during the work at Marica Arriba and it was found that his determinations agreed closely with those of two of us (Schapiro and Sweet). The other inspector who made the determinations from the Santiago district had been trained and repeatedly checked by one of us (Schapiro). This series of hemoglobin percentages is used with the egg counts from the same individuals to make comparisons between different groups in our series. These comparisons make it possible to approach some of the problems which have just been suggested.

B. Analysis of some of the hemoglobin determinations made by the Department of Uncinariasis in the course of the control campaign.

We will first give an analysis of some of the extensive series of hemoglobin determinations available in the reports of the Department of Uncinariasis. Most of them are from the reports of 1923 to 1926 and the discussion will also include some of the analyses which one of us (Schapiro) made in the 1925 and 1926 reports.

The records of a series of hemoglobins taken in 1925 and 1926 at the central office of the Department of Uncinariasis in Panama City are given in Table 1. The people represented in this series came from

TABLE 1.

Summary of hemoglobin determinations made in the central office of the Department of Uncinariasis in Panama City in 1925 and 1926.

	Positive for hookworm.	Negative for hookworm but positive for other parasites.	Negative for intestinal parasites.
Number of examinations.....	504	60	31
Average hemoglobin per cent.....	58.2	64.6	69.6

Panama City and its surroundings and probably have a lighter average

hookworm infestation than those of the interior. The small group, negative to all parasites, probably represents on the whole a better class of the population so that their high average hemoglobin index may be partly due to better conditions of life. It seems probable that an average of about 70 per cent. may be considered practically normal for hemoglobin determinations by the Talquist scale for the Panama population.

In 1923 a number of hemoglobin determinations were made from the city of Chitre which is one of the largest cities in the interior of Panama. Here the average hemoglobin percentage in 677 cases positive for hookworm was 59.6 per cent., or about the same as that of the Panama series. A still higher index was found this same year for the rural area of La Arena in the Province of Herrera where the average hemoglobin of 111 people who were hookworm positive was 61.2 per cent. This high average in a rural district was attributed to the fact that the negro race predominated in this area.

Beginning with 1925 hemoglobin determinations were made as a routine part of the preparation for treatment so that there are available in the reports of the Department of Uncinariasis for 1925 and 1926 large numbers of such examinations. Examinations were also made of treated patients from one to two months after treatment. We will therefore present part of the analyses for these two years which gives interesting information on the hemoglobin indices of hookworm positives of the town population as compared with the strictly rural group and also on the effect of treatment on the anemia.

TABLE 2.

Hemoglobin averages from examinations made by the Department of Uncinariasis in 1925.

	Before treatment.					After treatment.				
	Total no. of exams.	Av. hemo.	Distribution into hemoglobin groups.			Total no. of exams.	Av. hemo.	Distribution into hemoglobin groups.		
			0–55	56–75	75+			0–55	56–75	75+
Town group...	2,617	53.5	1,562	1,048	7	524	63	98	406	20
Rural group...	11,738	48.9	10,827	1,909	2	3,277	56.4	1,500	1,767	10

Table 2 gives hemoglobin averages from the 1925 report. These supplement our own records which are given later in this section since they are chiefly from the Provinces of Los Santos, Herrera and Panama

while ours are from Cocle and Verraguas. The town group includes a few examinations from Panama City but chiefly from places of less than a thousand people, while those from the rural districts are from small scattered villages or isolated houses.

It will be seen that although the numbers examined after treatment are much smaller than those examined before treatment they are quite large and the differences shown are probably characteristic of the improvement obtained in one or two months after treatment. It is especially significant that the proportion with hemoglobin percentages below 56 is much less after treatment. The higher average in the town group is probably due to better conditions of living although the degree of hookworm infestation may be lower. The extreme general anemia of the untreated rural group appears to be representative of an extremely heavy and widespread hookworm infestation for rural Panama.

The group with the lowest average hemoglobin in this series was from Ponuga in the uplands of Verraguas, where the average for 588 individuals was 45.4 per cent., with 577 with readings below 56 per cent. This is a situation similar to that at La Soledad described later in this paper. Comparable degrees of anemia are recorded in the 1926 series of examinations from rural districts near Porri and Pedasi in the province of Los Santos, which are situated near the sea coast on the coastal plain. At the first place the average hemoglobin in 2,110 individuals was 46.4 per cent. and in the second it was 45.7 per cent. in 985 individuals. Other instances from different parts of Panama might be given to illustrate the extreme degree of anemia found in certain of the rural districts.

It is interesting that when we compare our own records with those just given we find that the hemoglobin averages from the areas of the Penonome district, Cocle province, where we made our surveys are unusually high as compared with most of the records from elsewhere in Panama. The records from the Santiago district on the other hand agree closely with those from the other upland areas which were made by the Department of Uncinariasis. In the presentation of the records for the summer of 1926 we will constantly compare the hemoglobin averages with the average egg counts.

C. Analysis of the hemoglobin determinations made in the summer of 1926 from our Panama egg count series.

1. *General discussion.*

Hemoglobin determinations were made from a considerable number of the individuals from all the areas included in our egg count series.

We have combined these data for the various areas into four series, viz., (1) the determinations for the untreated individuals from the coastal plains group (Chorrerita, El Coco and Cocle), (2) those from the sanitated houses of Penonome, Rio Grande and Garicin, (3) those from Sardina and Marica Arriba and (4) those from La Soledad and La Atalaya. These groups represent the more important situations with which we dealt and their analysis makes it possible to compare the effect of the different degrees of hookworm infestation on the hemoglobin percentages of the people living under the different kinds of situations represented in our Panama studies.

2. *Hemoglobin analysis of an untreated group from the coastal plains area (Chorrerita, El Coco and Cocle).*

Table 3 gives the average hemoglobin percentages of 318 untreated individuals from the unsanitated villages of Chorrerita, El Coco and Cocle. The hemoglobin averages are lined up for the hookworm intensity groups with the average egg counts of the subgroups given for direct comparison. This series of hemoglobin determinations represents an unselected group from the coastal plains area (Chorrerita, El Coco and Cocle) which was discussed in Section V. It will be remembered that the level of hookworm infestation in this area while quite high as compared with other countries was considerably less than that of the hill and upland areas. These people are of the moreno type but with only a slight infusion of white blood. They are for the most part quite poor, they live under very primitive conditions, and many of them appear undernourished. Malaria both of the tertian and aestivo-autumnal types is quite prevalent during the rainy season and cases were beginning to appear at the time of our survey. When these conditions are considered in connection with their heavy hookworm infestation it seems very surprising that the hemoglobin averages are as high as they are shown to be in Table 3. In the adults they are only slightly reduced from the averages found in groups in Panama uninfected with hookworm and even in the children they are but little lower. There is some tendency for reduced hemoglobin averages to appear in the higher hookworm intensity groups, but the differences on the whole are surprisingly small. In the children the difference of 4.0 ± 1.8 found between the negatives and the highest intensity group (V) is not clearly significant in the light of its probable error. In the males, over nine years of age, the only significant difference is between groups III and V (4.7 ± 1.4), and in the females of the same age group there are no significant differences

TABLE 3.

The average hemoglobin percentages for the untreated individuals in Chorrerita, El Coco and Cocle lined up according to hookworm infestation intensity groups.

Intensity groups in eggs per c.c.	Children, 0–9 years.			Males, 10 years and over.			Females, 10 years and over.		
	No. of cases.	Av. eggs per c.c.	Av. hemoglobin per cent.	No. of cases.	Av. eggs per c.c.	Av. hemoglobin per cent.	No. of cases.	Av. eggs per c.c.	Av. hemoglobin per cent.
I. Negative	34	0	65.6 ± 0.7	1	0	70.0	2	0	70.0
II. 100–999	12	500	63.7 ± 2.3	5	700	70.0 ± 1.1	7	500	69.3 ± 1.5
III. 1,000–4,999	34	2,400	66.2 ± 0.9	18	2,600	71.4 ± 1.1	36	2,400	67.8 ± 0.8
IV. 5,000–9,999	18	7,300	67.2 ± 0.9	19	7,300	68.2 ± 1.0	19	7,300	69.5 ± 0.8
V. 10,000+	19	22,200	61.6 ± 1.7	48	30,400	66.7 ± 0.8	46	22,800	66.6 ± 0.7
Total group	117	5,500	65.2 ± 0.5	91	18,100	68.1 ± 0.5	110	11,600	67.7 ± 0.4

TABLE 4.

Correlation table between the size of the egg counts and hemoglobin percentages for the Chorrerita-El Coco-Cocle group.

a. Children, under 10 years.

Egg count group.	Hemoglobin count.											Total.
	80	75	70	65	60	55	50	45	40	35	30	
Negative	1	4	7	12	6	4	1					35
100–3,999	2	10	12	11	7	3		2			1	48
4,000–7,999	1	3	4	6	4	1						19
8,000–11,999		1	3	1	1	1					1	8
12,000–15,999		1	1	2				1				5
16,000–19,999			1	2	1							4
20,000–23,999			1		1							2
24,000–27,999		1						1				2
28,000–31,999					2							2
32,000–35,999					1							1
36,000–39,999				1								1
40,000–43,999				1								1
Total	4	20	29	36	23	9	1	4			2	128

Coefficient of correlation $= .104 \pm .069$.

b. Adults and children over 10 years.

Negative	2	1		2								5
100–3,999	4	23	29	10	12	1		1				80
4,000–7,999	4	10	17	6	10							47
8,000–11,999	2	7	9	4	4	1						27
12,000–15,999	1	3	6	5	4			1				20
16,000–19,999		2	5	4	3	1						15
20,000–23,999		4	4	8								16
24,000–27,999		2	3	2								7
28,000–31,999			3	4	1							8
32,000–35,999		2	3	1	4							10
36,000–39,999		1	3	2			1					7
40,000–43,999				1								1
44,000–47,999		1	1	2								4
48,000–51,999												0
52,000–55,999												0
56,000–59,999					1							1
60,000–63,999			3	1		1						5
70,400						1						1
71,800			1									1
92,600			1									1
96,200				1								1
102,000											1	1
Total	13	56	88	53	39	5	1	2			1	258

Coefficient of correlation $= .148 \pm .041$.

between group V and any of the others. When the high average egg counts for group V are considered (Table 3) it is very surprising that there should not be a greater reduction in hemoglobin averages in this intensity group as compared with the others. When a correlation table is set up between the egg counts and hemoglobin percentages of this series (Table 4, *a* and *b*), the coefficients of correlation obtained are $-.1043 \pm .0692$ for the group under 10 years and $-.1477 \pm .0415$ for those over 10 years. Such a slight negative correlation suggests the presence of factors which tend to keep up the hemoglobin percentages in the more heavily infested groups.

3. *Hemoglobin analysis of a group of both treated and untreated individuals living in sanitated houses in Penonome, Rio Grande and Garicin.*

Table 5 gives the analysis of a large series of hemoglobin determina-

TABLE 5.

Average hemoglobin percentages of Penonome, Rio Grande and Garicin as influenced by age and previous treatment. (These people are all from sanitated houses.)

Intensity groups in eggs per c.c.	Children, males and females, 1 to 9 years.		Males and females, 10 years and over.			
	Treated and untreated.		Treated.		Untreated.	
	No. of cases.	Av. hemoglobin per cent.	No. of cases.	Av. hemoglobin per cent.	No. of cases.	Av. hemoglobin per cent.
I. Negative	65	66 ± 0.6	18	67 ± 1.3	19	71 ± 1.6
II. 100–999	38	62 ± 1.0	25	70 ± 0.6	18	65 ± 1.1
III. 1,000–4,999	33	63 ± 0.8	37	68 ± 0.9	50	67 ± 0.7
IV. 5,000–9,999	12	64 ± 1.6	13	71 ± 1.3	38	66 ± 0.7
V. 10,000+	13	60 ± 1.3	24	67 ± 0.9	44	63 ± 0.7
Total	161	64 ± 0.4	117	69 ± 0.4	169	66 ± 0.4

tions, including both treated and untreated individuals which represents a majority of the persons examined from Penonome, Rio Grande and Garicin who lived in houses with latrines. The levels of hookworm infestation of the areas for which these hemoglobin averages are representative are discussed in Section VI. They are considerably lower than any of the other areas, a reduction which we interpreted as due to the influence of treatment and sanitation. Since there were no significant differences between the hemoglobin averages of these individual communities, the males and females, and of the

treated and untreated children these subdivisions do not appear in Table 5. The people of these three communities are of about the same type as those of Chorrerita, El Coco and Cocle but they appeared on the average to be in a somewhat better economic condition. Malaria is also quite prevalent throughout these areas.

Reference to Table 5 shows that the treated individuals have a significantly higher hemoglobin average than the untreated. This corresponds with a considerably higher average infestation for the untreated group from this area as shown in Section VI. A like difference between the treated and untreated individuals was, as already noted, not present in the children. That there is some relation in this series between increasing intensity of infestation and lower hemoglobins is shown by the difference between the treated and untreated individuals and by the fact that in both the untreated children and adults the highest intensity group (V) has a significantly lower hemoglobin than the other groups (Table 5). No significant negative correlation, however, was present between the hemoglobin percentages and the size of the egg counts when the individual cases were set up in a correlation table, and the differences between Group V and the other groups and between the treated and untreated adults is really quite small.

Another point of interest is that in the treated individuals, both children and adults, there were no significant differences between the higher and lower intensity groups. It looks from this as if the improvement in hemoglobin produced by treatment remained even after considerable reinfection. This fits in with the situation shown in Table 5, in which there is a significantly higher hemoglobin average for the treated individuals as compared with the untreated in the two highest intensity groups (IV and V).

4. *Hemoglobin analysis from Sardina and Marica Arriba.*

Table 6 gives the analysis of the series of hemoglobin determinations obtained from Sardina and Marica Arriba which represents over 80 per cent. of the egg count series from these two villages. The people of these places were of much the same type as those of the rest of the Penonome district. Apparently there was a smaller proportion of white blood in these people than in the other villages and there appeared to be a considerable amount of negro blood especially in Marica Arriba. The malaria situation was no better than elsewhere in the district but these people were better off economically and appeared better nourished than any of the others of this region. While they had extremely heavy hookworm infesta-

TABLE 6.

The average hemoglobin percentages for Sardina and Marica Arriba lined up according to hookworm infestation intensity groups.

Intensity groups in eggs per c.c.	Children, 0–9 years.			Males, 10 years and over.			Females, 10 years and over.		
	No. of cases.	Av. eggs per c.c.	Av. hemoglobin per cent.	No. of cases.	Av. eggs per c.c.	Av. hemoglobin per cent.	No. of cases.	Av. eggs per c.c.	Av. hemoglobin per cent.
I. Negative	11	0	56.8 ± 0.8	0			0		
II. 100–999	6	400	59.2 ± 1.6	0			2	400	60.0
III. 1,000–4,999	7	3,500	64.3 ± 1.4	10	2,900	64.5 ± 1.5	8	2,300	63.1 ± 2.3
IV. 5,000–9,999	9	8,300	62.8 ± 1.7	11	7,100	63.2 ± 1.2	14	7,700	66.1 ± 1.4
V. 10,000+	17	15,600	60.6 ± 1.0	54	35,100	64.2 ± 0.8	28	26,100	62.5 ± 0.9
Total group	50	7,300	60.6 ± 0.6	75	26,700	64.1 ± 0.6	52	16,500	63.5 ± 0.7

tions their appearance, general activity and physical condition were not suggestive of any considerable amount of clinical hookworm disease. In fact after we actually knew the size of the egg counts in these two villages it seemed astonishing that a group of people could carry such a heavy hookworm burden and remain so active, economically efficient and show so few signs of disease.

It can be seen by comparing Table 6 with Tables 3 and 5 that the people of Sardina and Marica Arriba showed a significantly lower average hemoglobin both for the children and the adults than the other groups from the Penonome district. These differences are, however, quite small when the much greater intensity of the infestation is considered.

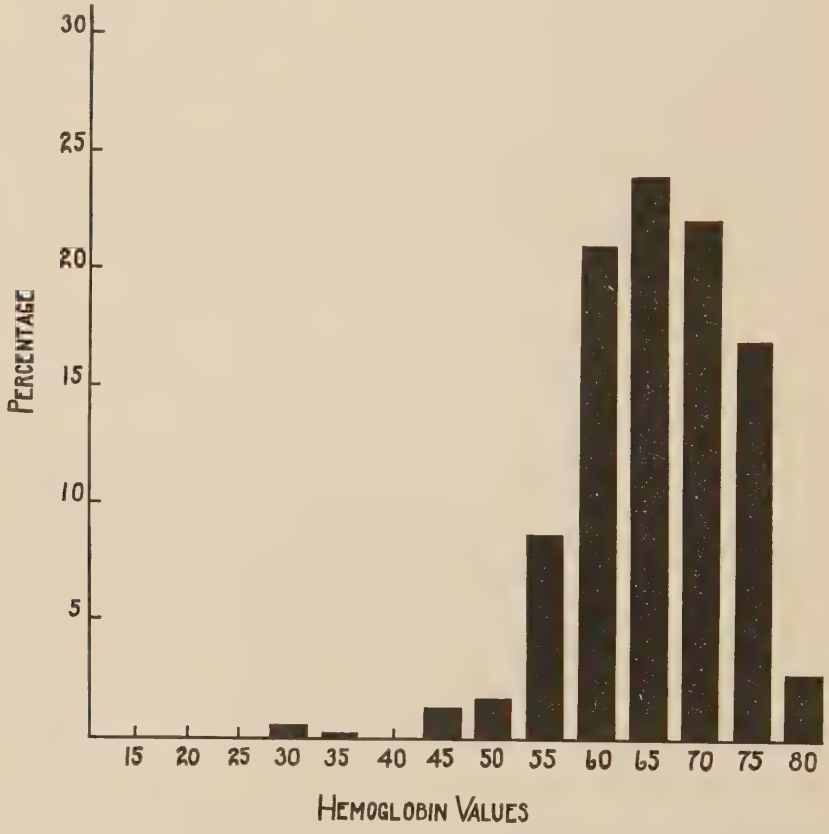
It can be seen by comparing the hemoglobin averages in Table 6 in the light of their probable errors that no significant differences whatever are present between the highest intensity group and any of the others. There is also no negative correlation between the individual hemoglobin percentages and the size of the egg counts.

5. *Discussion of the hemoglobin data for the different groups of the Penonome district (Cocle province).*

Although the three groups of people just discussed from Cocle province offer considerable variation in the intensity of their hookworm infestations, the differences in average hemoglobin percentages are very small. In fact for all three areas the average hemoglobin percentages are surprisingly high and the number of cases with readings of 55 per cent. or below is surprisingly small. This is illustrated in Graph 1 which shows the percentage of the total cases from the Chorrerita-El Coco-Cocle and the Sardina-Marica Arriba series which fall into each of the hemoglobin percentage groups.

As already stated there is in the hemoglobins taken from the Penonome district no negative correlation between the individual hemoglobin percentages and the size of the egg counts as illustrated by Table 4. Further there are only a few instances in which there are significant differences which in every case are small between the hemoglobin averages of the different intensity groups. This is very astonishing when the size of the infestation in intensity Group V in the three series is considered in comparison with those of the other groups. In other words it is apparent that the hemoglobins in this series either of individuals or groups are very slightly influenced by the degree of hookworm infestation. This point is still further emphasized when the hemoglobin percentages of the 32 cases with

egg counts over 50,000 eggs per c.c. are considered (Table 7). For these cases the average egg count reaches the extraordinary figure of 87,700 eggs per c.c., while the average hemoglobin is 59.4 which is almost unbelievably high for a group with such enormous infestations. Only three of these cases with hemoglobins of 30, 35 and 35 respectively present the picture of anemia that would be expected in such cases, while the majority have hemoglobins of 60 or above.



GRAPH 1. Analysis of the hemoglobins for Chorrerita, El Coco, Cocle, Sardina and Marica Arriba according to the percentage of the total number with the different hemoglobin values.

The other side of the picture is shown by an analysis of the cases, 22 in number, from Cocle province which have very low hemoglobin percentages (45 per cent. or lower). All of these cases except three are quite lightly infested with hookworms. For these 22 cases the average egg count is 19,700 eggs per c.c. and the average hemoglobin

is 41.1 per cent. If the heaviest three cases are removed a series of 19 cases is left with an average egg count of 5,900 and an average hemoglobin of 42.4 per cent. There seems to be little evidence, therefore, from this series that these low hemoglobins which are

TABLE 7.

Egg counts and hemoglobin percentages of cases from the areas of the Penonome district (Cocle province) with egg counts over 50,000 eggs per c.c.

Case no.	Sex.	Age.	Av. egg count in eggs per c.c.	Hemoglobin per cent.
1.....	M.	5–7	101,900	50
2.....	M.	10–11	55,200	60
3.....	M.	10–11	100,800	50
4.....	M.	12–14	55,200	60
5.....	M.	12–14	64,400	70
6.....	F.	12–14	146,400	35
7.....	M.	15–17	53,200	60
8.....	M.	15–17	76,800	70
9.....	F.	15–17	125,600	50
10.....	M.	18–19	165,600	80
11.....	M.	20–24	59,000	70
12.....	M.	20–24	59,200	70
13.....	M.	20–24	63,600	75
14.....	M.	20–24	102,000	30
15.....	M.	20–24	102,000	55
16.....	M.	25–29	64,000	70
17.....	M.	25–29	77,100	60
18.....	M.	25–29	85,800	60
19.....	M.	25–29	96,200	65
20.....	F.	30–34	60,000	55
21.....	M.	30–34	62,800	55
22.....	M.	35–39	92,600	70
23.....	F.	40–44	70,400	55
24.....	M.	40–44	208,400	50
25.....	M.	45–49	61,000	70
26.....	M.	45–49	73,600	35
27.....	M.	45–49	81,600	50
28.....	F.	50–55	54,700	65
29.....	F.	55–59	61,400	70
30.....	M.	60	60,200	65
31.....	M.	60+	107,200	70
32.....	F.	72	159,800	50
Total.....			2,807,700	900
Average....			87,700	59.4

mostly in children are primarily caused by their hookworm infestation, since comparable groups in our series with much higher egg counts have considerably higher average hemoglobin values.

It can be seen from the above discussion that the people of Cocle province appear to have a very unusual resistance to the anemia producing effect of hookworm infestation. This does not seem to be due to especially good food and living conditions since some of the people (for example the Chorrerita, El Coco and Cocle group) are very poor and evidently have an insufficient diet. It seems very suggestive to us that this group has comparatively little white blood, and it does not seem unreasonable to suggest a racial resistance in this mixture of Indian and negro blood to the effect of hookworm infestation. It should be noted, however, that no such resistance was found by Carr (1926) in his Mexican group in which Indian blood predominated. Fülleborn, Dios, and Luccarini (1928) have recently reported a similar situation in Corrientes province in northern Argentine. Here the hemoglobin was only slightly influenced by the worm burden, the adults showing almost no reduction even in the heaviest cases. Even in the children under ten the reduction was comparatively small. The authors suggest that the cause of this resistance is a good diet and the preponderance of Indian blood. They also consider that the adults have developed a relative immunity against new infection.

6. *Hemoglobin analysis of a group from La Soledad and La Atalaya.*

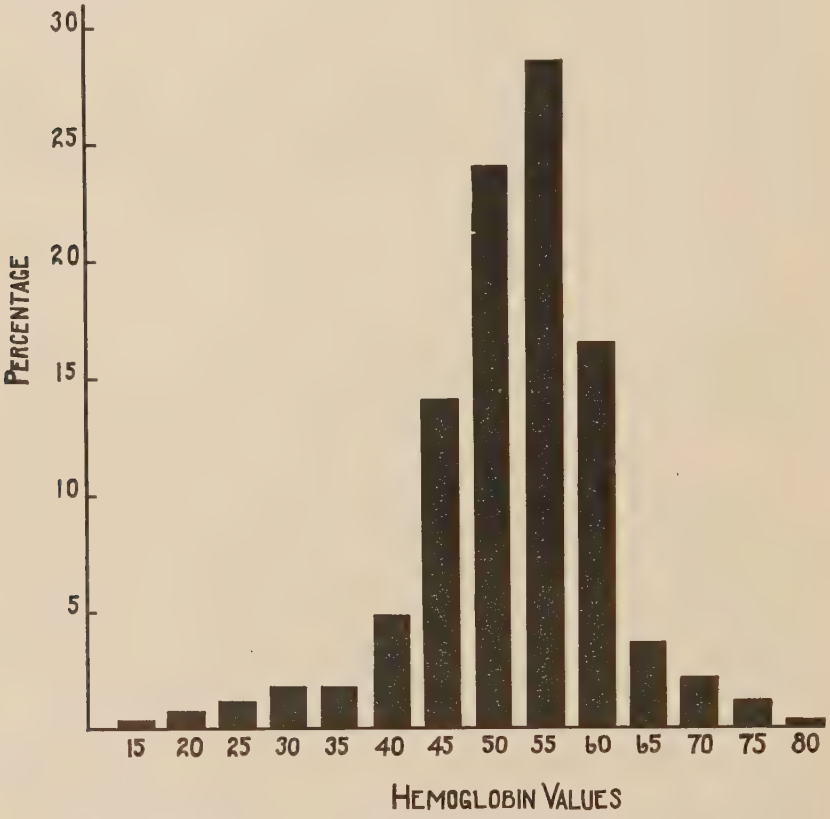
Table 8 gives the analysis of the hemoglobin percentages of a series of 314 cases representative of La Soledad and La Atalaya, which are located in the Santiago district in Veraguas province. The hookworm infestation of these places has been discussed in Sections V and VI and is believed to be characteristic of the upland regions of Panama. Some control work had been done in La Atalaya but since the average hemoglobin percentage from this place was not significantly lower than that for La Soledad they will be considered together for comparison with the areas of the Penonome district in Cocle province. The people of the Santiago district are strikingly different from those of the Penonome district since there is a very marked infusion of white blood, making them appear almost a white population as contrasted with the colored appearance of the other groups. The people of La Soledad and part of those from La Atalaya are quite poor, and many appear undernourished but they could hardly be considered any poorer than those of the villages of Chorrerita,

TABLE 8.

The average hemoglobin percentages for La Soledad and La Atalaya lined up according to hookworm infestation intensity groups.

Intensity groups in eggs per c.c.	Children, 0–9 years.			Males, 10 years and over.			Females, 10 years and over.		
	No. of cases.	Av. eggs per c.c.	Av. hemoglobin per cent.	No. of cases.	Av. eggs per c.c.	Av. hemoglobin per cent.	No. of cases.	Av. eggs per c.c.	Av. hemoglobin per cent.
I. Negative	10	0	48.0 ± 0.9	4	0	60.0 ± 3.6	6	0	50.8 ± 2.0
II. 100–999	11	500	51.4 ± 0.8	6	500	65.8 ± 2.4	10	300	57.0 ± 1.8
III. 1,000–4,999	21	3,200	51.2 ± 0.6	11	3,600	58.6 ± 1.5	31	3,100	55.3 ± 0.9
IV. 5,000–9,999	21	7,200	49.5 ± 0.9	11	6,900	55.9 ± 1.8	30	7,300	53.0 ± 0.7
V. 10,000+	31	25,300	43.5 ± 1.3	76	27,800	52.8 ± 0.7	56	21,000	50.3 ± 0.8
Total groups	94	10,700	48.0 ± 0.5	108	20,600	54.7 ± 0.6	133	11,200	52.6 ± 0.5

El Coco and Cocle. A few of those living around the central square of La Atalaya are distinctly better off and live under conditions comparable to those of the better classes of the town of Penonome. La Soledad had the highest average infestation of our whole Panama series but it was only slightly higher than that of Sardina and Marica Arriba. Many of the people of La Soledad and La Atalaya looked distinctly anemic and even a casual survey showed numbers of individuals who would be classed as suffering from severe clinical hookworm disease.



GRAPH 2. Analysis of the hemoglobins for La Soledad and La Atalaya according to the percentage of the total number with the different hemoglobin values.

An examination of Table 8 shows that in contrast with the groups from Cocle province these people were distinctly anemic. This is also shown in Graph 2 by the high proportion of the group with the lower hemoglobin percentages as compared with the Cocle province

groups in Graph 1. That this difference was not due to heavier infestation is shown by the fact that the adults in the La Soledad-La Atalaya series had about the same average infestation as those of the Chorrerita-El Coco-Cocle group, and a distinctly lower infestation than those of the Sardina-Marica Arriba group. In the children only was the infestation distinctly heavier than in the Cocle province groups. It seems impossible, therefore, to attribute the 10 to 15 points reduction in the hemoglobin averages of the La Soledad and La Atalaya group to their heavier hookworm infestation. Nor does it seem possible to attribute it to malaria or any environmental factor. The only explanation that we can suggest is the possibility that there is a greater susceptibility to the anemia producing effect on their worm burden in the La Soledad-La Atalaya series due to their white blood as compared with the greater resistance of the Indian-negro mixture of the Penonome region.

If this be true, there should be some correlation at least in this group between the intensity of the infestation as measured by the egg count and the hemoglobin percentages. We, therefore, set up a correlation table between these two factors (Table 9) which shows a negative correlation in the series of individuals considered ($-$ .3414 $\pm$ .0646 for the 0–9 group and $-$ .2637 $\pm$ .0412 for those over 9 years). If Table 9 is studied carefully it becomes evident that there are two main reasons why the coefficient of correlation is not larger. The first is that there is present a small group of extremely heavy cases with high hemoglobins. These cases influence the coefficient very greatly on account of the comparatively large size of their egg counts. They apparently present the same type of resistance to their heavy worm burdens that was found in so many cases from Cocle province. The other important factor which disturbs the correlation is a group of cases of considerable size, many of whom are young children, which are found in the lowest egg count group but with hemoglobin percentages of 50 or lower. Such a large group with low egg counts and low hemoglobins shows the action of other anemia producing factors, such perhaps as severe malaria or malnutrition. For these reasons the rather low negative correlation does not necessarily mean that the intensity of hookworm infestation in this series is not associated with anemia but that there are present obscuring factors. This contention is supported by the consideration of the hemoglobin averages according to intensity groups of hookworm infestation as shown in Table 8. Here there is a distinct trend toward a reduced hemoglobin in the higher intensity groups, which contrasts

TABLE 9.

Correlation table between the size of the egg count and the hemoglobin for La Soledad and La Atalaya.

a. Children, under 10 years.

Egg count group.	Hemoglobin count.														Total.
	80	75	70	65	60	55	50	45	40	35	30	25	20	15	
Negative						2	2	6							10
100–3,999					1	12	10	5							28
4,000–7,999					1	6	7	4	2	1					21
8,000–11,999						3	3	2							8
12,000–15,999							2								2
16,000–19,999						2			1						3
20,000–23,999						1	1	2					1		5
24,000–27,999						2	1	2	2		1	1			9
28,000–31,999						1			1	1			1		4
32,000–35,999												1			1
36,000–39,999						1									1
40,000–43,999								1	1						2
44,000–47,999										1					1
Total					2	30	26	22	7	3	1	2	2		95

Coefficient of correlation $= .3414 \pm .0646$.

b. Adults and children 10 years and over.

Negative		1			1	3	2	1	1						9
100–3,999	1	1	2	5	18	7	5	2			1				42
4,000–7,999			1	2	9	16	11	6		1					46
8,000–11,999		1	1	2	6	10	10		2			1	1		34
12,000–15,999		1			6	7	5	1	1						21
16,000–19,999			1	1	5	7	3	2	1	1					21
20,000–23,999				1	4	3	6	3			1				18
24,000–27,999					2	2	2	2	1						9
28,000–31,999			1			1	1	2	1						6
32,000–35,999				1	1	6	5	1							14
36,000–39,999							1		1						2
40,000–43,999						1	1	2	1		1				6
44,000–47,999											2				2
48,000–51,999							1	1		1					3
52,000–55,999															0
56,000–59,999			1			1		1							3
60,000–63,999						1		1							2
73,600												1			1
80,000						1									1
84,800							1								1
Total	1	4	7	12	52	66	54	25	9	3	5	2	1		241

Coefficient of correlation $= .2637 \pm .0412$.

very definitely with the situation described for the groups from the Penonome district (cf. Tables 3, 5 and 6). A comparison of Table 4 with Table 9 further emphasizes the differences in the effect of the hookworm infestations on the hemoglobins in these two regions.

When the cases with hemoglobin percentages of 45 or below are considered from the La Soledad-La Atalaya group, they also show for both children and adults egg count averages which are very much higher than the total series in these groups (Table 10).

TABLE 10.

Comparisons of the average hemoglobin percentages with the average egg counts in individuals of the La Soledad-La Atalaya group with a hemoglobin of 45 per cent. or lower.

Group.	No. of cases.	Av. hemoglobin per cent.	Av. egg count per c.c.
Males and Females, 0–9 years.....	36	42.2	15,100
Males, 10 years and over.....	16	39.4	36,200
Females, 10 years and over.....	29	40.5	16,800

All these facts taken together demonstrate rather conclusively that the size of hookworm infestations in the La Soledad-La Atalaya group has a relation to anemia production in a way that is not true in any of the groups from the Cocle province. We feel inclined to attribute this difference to a difference of race, although the evidence for this can hardly be considered as conclusive and there may be other unknown factors present which account for at least part of the difference.

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VIII. QUANTITATIVE STUDIES ON THE DISTRIBUTION OF *ASCARIS LUMBRICOIDES* AND *TRICHURIS TRICHIURA* IN PANAMA.

By

W. W. CORT, N. R. STOLL, W. A. RILEY and W. C. SWEET.

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A. Introduction.

Egg counts for all the intestinal worms present were made of the complete series of cases examined by our expedition in Panama. There is, therefore available for the study of the distribution of

Ascaris lumbricoides and *Trichuris trichiura* a series of dilution egg counts of 2,247 cases from the eleven different population groups for which the hookworm situation was studied (Sections V and VI). The use of the dilution egg-counting method to measure the infestations with these two parasites has the same general advantages over the use of incidence statistics only that have been stressed so often in the recent work on the hookworm problem. We do not, however, have as much information for these parasites as for the hookworm on the variability of the egg count or on the egg-worm ratio. Two studies from the work of the Panama expedition already published (Brown, 1927*b*, and Brown and Cort, 1927) have a bearing on these questions. Brown, from a study of four cases, finds no evidence of periodicity in the egg output from day to day for *Necator americanus*, *Ascaris lumbricoides* and *Trichuris trichiura*, and concludes that the egg production is equally regular in all three species. In the other paper the egg production per female worm was found for *Ascaris lumbricoides* to be about 2,000 eggs per gram. Davis (1924, 231) obtained even a higher figure. From the 16 cases in which he obtained egg-worm ratios for ascaris he recovered 56 female worms and 37 males. From this series his averages give 774,655 eggs per day per female worm and 3,466 eggs per gram per female ascaris. More recently Manalang (1928*b*) has estimated the egg output of female ascarids in eleven autopsy cases to be about 1,400 eggs per gram per female worm (basis formed stool) and Augustine, Nazmi, Helmy and McGavran (1928) in a careful study of the egg-worm correlation in 27 cases in Egypt found that the number of eggs per female ascaris per c.c. of stool (formed basis) was about 2,700. This enormous fecundity is in line with the large size of these worms and also with the large size of the egg counts in our series. In fact the use of the 2,000 eggs per gram figure in estimating the number of worms present from the egg counts gives an average number of worms which seems to fit in fairly well with the information we have from treatments of the size of ascaris infestations. With trichuris we ourselves have not been able to make any egg-worm correlations. Moosbrugger (1895) has estimated in one case that 3,000 eggs per gram corresponded to about 900 worms. This gives an estimated egg production per female worm only a fraction of that of *Necator americanus*. Manalang (1928*a*) on the other hand reports an unexpectedly high figure for trichuris egg production. He estimated the egg production per female worm to be 310 per gram (formed basis) for nine post mortem cases without intestinal pathology and as 669 eggs per gram per female worm for 9 cases showing

intestinal pathology. It is difficult to believe that either of these figures represents the true egg-worm ratio in this species since in the first case the egg production is much less than that for *Necator americanus* and in the second it is surprisingly large. It is evident that more studies are badly needed to give us a clearer understanding of the variability of the egg count in ascaris and trichuris and on the egg-worm correlation in these species.

In the meantime it seems perfectly safe to postulate that the use of the egg count as an estimate of the size of infestations in ascaris and trichuris is valid if large groups are considered and if comparisons are drawn with a rather wide allowance for variability.

B. Analysis of the Panama egg count data for *Ascaris lumbricoides.*

1. *Distribution of ascaris according to age and sex in the whole Panama group.*

Since the ascaris counts represent exactly the same series as the hookworm counts analyzed in detail in Sections V and VI and are from the places already described in Section I, it will be unnecessary to repeat the enumeration of the different population groups included in our series except to again state that they appear to represent a pretty good cross-section of that large majority of the population of Panama that lives on the Pacific slope west of the Canal Zone. Of the total series of egg counts for 2,247 different individuals 51 per cent. were positive for *Ascaris lumbricoides,* the percentage being 50.9 per cent. in the 1,052 males and 51.2 per cent. in the 1,195 females. The incidence is slightly higher in the children with 57.3 per cent. infested in the 804 individuals in the group up to 9 years of age and 47.5 per cent. in the 1,447 individuals 10 years of age and over. Certain minor fluctuations in the incidence between males and females of the different age groups can be figured from Table 1.

The average ascaris egg count per c.c. for the total series of 2,247 cases is 17,990, it being for the 1,052 males 15,090 and for the 1,195 females 20,540. These averages corrected for the standard population (Section IV) are for both males and females 16,500, being 13,420 for the males and 19,590 for the females. It is of interest to consider the average egg counts for the positive cases only, which for both sexes is 35,250 eggs per c.c., for the males 29,670 and for the females 40,120. Accepting for the sake of comparison the tentative figures for egg-worm correlation given in the paper by Brown and Cort (1927) this means an average of about 35 adult ascarids per case for

all the positive cases and about 30 for the males and 40 for the females. The average for the positives in the children under 10 years of age would be on this basis somewhat above 50 adult worms and that for those 10 years of age and over only slightly over 20.* According to this same factor the infestation of the individual cases would vary from a single worm to over 700. It is evident that the egg production of the female worms cannot be very much less than 2,000 per c.c. without making the size of the estimated worm burdens much heavier than what we would expect from our general knowledge of the size of

TABLE 1.

Analysis of total series of ascaris counts for Panama into intensity groups.†

Males.

Intensity groups in eggs per c.c.	0–9		10–19		20–39		40+		Total.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Negative	172	41.9	122	45.7	134	58.3	89	61.4	517	49.1
1–9,999	85	20.7	74	27.7	62	26.9	39	26.9	260	24.7
10,000–49,999	81	19.8	61	22.8	28	12.2	14	9.6	184	17.5
50,000–99,999	40	9.8	8	3.0	5	2.2	2	1.4	55	5.2
100,000+	32	7.8	2	.7	1	.4	1	.7	36	3.4
Total	410		267		230		145		1,052	

Females.

Negative	171	43.4	115	40.8	163	51.7	134	65.7	583	48.8
1–9,999	85	21.6	66	23.4	71	22.5	48	23.5	270	22.6
10,000–49,999	61	15.5	60	21.3	61	19.4	19	9.3	201	16.8
50,000–99,999	34	8.6	29	10.3	14	4.4	1	.5	78	6.5
100,000+	43	10.9	12	4.3	6	1.9	2	1.0	63	5.3
Total	394		282		315		204		1,195	

* On account of the small size of the stools of children, especially those under 6 years of age (Section III), the size of the egg counts given in young children must be considerably discounted when compared with adults. This figure, therefore, which is based on the actual egg count is certainly too high.

† The intensity groups for the analysis of the ascaris counts were arbitrarily chosen and have no particular significance except that they seemed to us to be convenient subdivisions. Using Brown's figure for egg-worm correlation the second group would have under 10 adult worms, the third from 10–49, the fourth from 50–99 and the fifth over 100. Such figures must be considered as only rough estimates and subject to revision as we obtain further information on the egg-worm correlation in this species.

ascaris infestations. The validity of this point can be easily seen by hypothecating smaller factors and applying them to the averages just given of the positive cases or to the averages of various groups as they appear in the tables.

In the analysis into intensity groups given in Table 1, it is interesting to note that between 70 and 75 per cent. of the cases fall in the negatives and the lightest group in which the maximum is estimated at about 10 adult worms, and only about 10 per cent. are in the two heaviest groups where the infestations are estimated as being somewhat over 50 worms per case.

The cases in the heaviest intensity group are of very great significance since they are widely scattered in different population and age groups. The presence of any of these cases in particular groups, especially when the numbers are small, very greatly influences the averages so that they have to be taken into consideration in nearly every comparison that is made. While these 99 cases represent only

TABLE 2.

Average egg count per c.c. for ascaris infestations in Panama according to age and sex.

Age groups.	Males.		Females.	
	No. of cases.	Average egg count per c.c.	No. of cases.	Average egg count per c.c.
0–2	98	21,210	89	27,790
3–4	103	34,720	99	38,420
5–7	125	36,520	114	46,630
8–9	84	16,560	92	23,140
10–11	69	12,390	68	36,630
12–14	88	8,490	90	20,870
15–17	75	7,530	77	13,470
18–19	35	7,300	47	19,130
20–24	57	4,170	97	10,740
25–29	66	5,170	62	12,520
30–34	55	7,410	77	12,300
35–39	52	5,020	79	9,840
40–44	42	3,630	49	2,130
45–49	24	1,850	49	2,900
50–54	30	3,950	33	4,210
55–59	15	310	26	14,210
60+	34	7,940	47	4,800
Total	1,052	15,090	1,195	20,540
Corrected average		13,420		19,590

about 4 1/2 per cent. of the total series they represent over 49 per cent. of the total egg count. This means that practically 50 per cent. of the ascarids present in this whole group are concentrated in heavy cases representing less than 5 per cent. of the total individuals.

Table 2 gives the details of the analysis of the Panama ascaris counts according to age and sex. It can be seen from this table that in the younger age groups the average infestation both of the males and the females is very much higher than in the older groups. This is especially true in the group under 10 years of age. This is true even after a very liberal reduction for stool size. The findings in Section III suggest that in the 0–2 group the count should be divided by four and in the 3–4 group by two to get nearer the true figure. This interpolation gives a more reasonable size for the egg counts in the very youngest children. Assuming that a somewhat smaller reduction is necessary in the 5–7 age group the peak of infestation remains in the males in this group, but would probably be shifted to the females in the 10–11 group. These changes do not in any way alter the general conclusions which have been drawn from the differences in the size of infestations in children and adults. The higher averages in the children are influenced to an extraordinary degree by the concentration in the children of the heavy cases since 75 out of a total of 99 cases over 100,000 eggs per c.c. are in the 0–9 group. It is also interesting to note that in the males the average infestation drops very rapidly after about the 7th to 9th year while in the females

TABLE 3.

Age group analysis of Panama ascaris series (see Graph 1a and 1b).

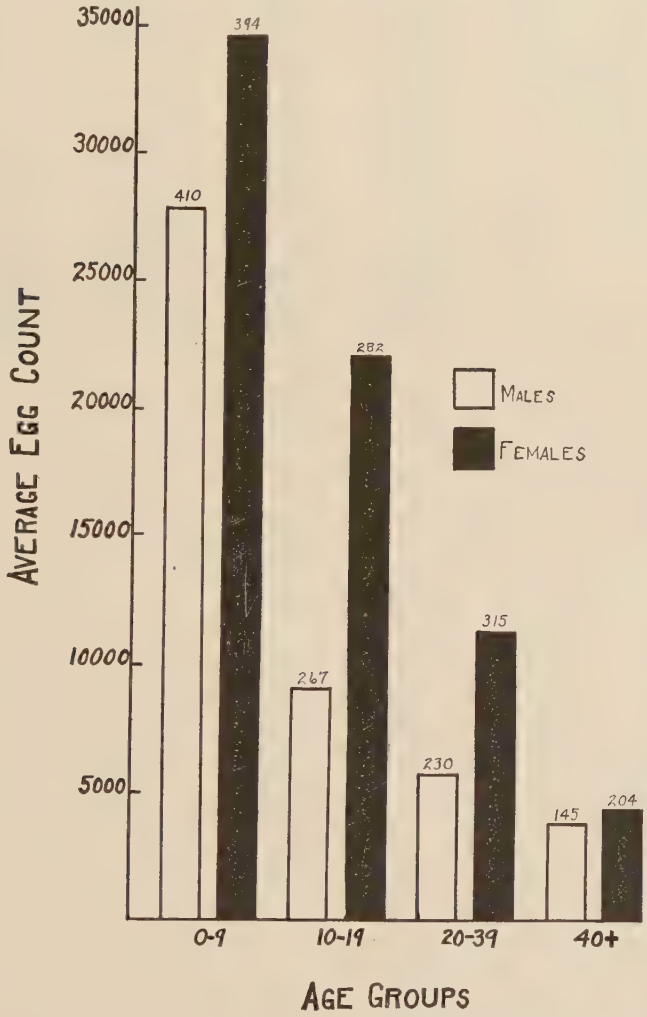
a. Original series of 2,247 cases.

Age group.	Males		Females	
	No. of cases.	Average count.	No. of cases.	Average count.
0–9.....	410	28,320	394	34,830
10–19.....	267	9,070	282	22,360
20–39.....	230	5,420	315	11,250
40+.....	145	4,070	204	4,320

b. Series with cases of 100,000 eggs per c.c. and over removed.

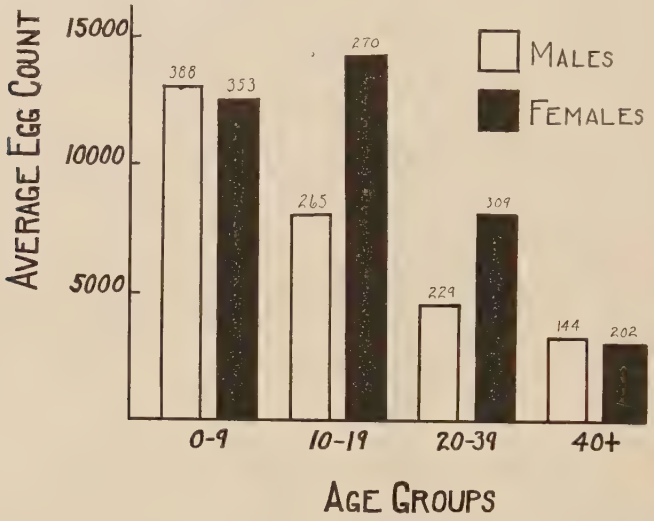
0–9.....	388	13,350	353	12,670
10–19.....	265	8,260	270	14,470
20–39.....	229	4,560	309	8,260
40+.....	144	3,380	202	3,180

the drop comes somewhat later. The corrected average egg count in the females as already noted is very much greater than in the males. This is partly due to the fact that 63 of the cases in the highest intensity group are in the females as compared with 36 in males. It is helpful in comparing the infestations in the sexes to use larger age groups (Table 3*a*). From this table and Graph 1*a* it can be seen that in the ages from 10 to 39 the females have a very much heavier



GRAPH 1*a*. Comparisons of the egg counts of ascaris in the Panama series for age and sex. Original series of 2,247 cases. The numbers above the bars represent the number of cases averaged.

average infestation than the males. It was thought that it might be of interest to determine to what extent the heavier infestation, in the females, was due to a comparatively few heavy cases. Therefore, in Table 3*b*, and Graph 1*b* the averages are set up with the cases of



Graph 1*b*. Comparison of egg counts of ascaris in the Panama series for age and sex. Series with cases of 100,000 eggs per c.c. and over removed.

100,000 eggs per c.c. and over taken out. It can be seen by comparing this second group with the first that the higher average infestation in both the males and females in the 0–9 year group was probably due entirely to the distribution of the heaviest cases, but that, from 10–39 years the females have considerably higher averages than the males, both before and after the removal of the heaviest cases.

The greater intensity of the infestation in the females from 10–39 years of age is even more clearly brought out by the analysis into intensity groups (Table 1) which shows a much larger percentage of the females than the males of these ages in the higher intensity groups.

2. *Ascaris infestation by families.*

Some of the peculiarities of the distribution of ascaris infestation in our Panama series are made clear by a study of infestation according to representative families. We chose for this study all families in our series from which we had egg counts for at least five individuals unless specimens for examination were lacking for more than two members. This gives a series of 161 family groups in which every

TABLE 4.

Family groups from Panama areas showing concentration of ascaris infestation.

Area.	House no.	Age.	Sex.	Ascaris egg count per c.c.
Penonome	441	45	F.	15,800
		25	M.	0
		21	F.	500
		8	M.	5,200
		13	F.	69,800
		3	M.	114,800
	Average....			34,350
Rio Grande	11	30	F.	46,400
		12	M.	35,400
		10	M.	47,400
		8	M.	84,200
		6	F.	53,200
	Average....			53,320
Rio Grande	63	35	F.	12,900
		21	M.	800
		19	F.	0
		17	F.	0
		15	F.	206,000
		13	M.	57,800
		9	F.	160,000
		23	F.	2,900
		3	F.	335,200
		1 1/12	M.	0
		18	M.	0
	Average....			70,510
Rio Grande	70	70	F.	0
		32	F.	300
		8	F.	34,600
		6	F.	378,100
		6	F.	13,200
	Average....			85,240
Garicin	30	29	M.	3,000
		56	F.	100
		31	F.	12,000
		15	M.	10,200
		3	F.	413,600
		1 1/2	F.	0
	Average....			73,150

TABLE 4 (*Continued*).

Area.	House no.	Age.	Sex.	Ascaris egg count per c.c.
El Coco	15	30	M.	203,800
		28	F.	12,400
		7	M.	46,800
		3	F.	2,000
		1	M.	0
		12	M.	5,000
	Average....			45,000
Garicin	40	48	M.	0
		19	F.	0
		16	F.	35,800
		11	M.	47,900
		6	F.	403,000
		6/12	M.	0
	Average....			81,120
Garicin	42A	32	F.	177,800
		8	F.	317,000
		7	F.	141,000
		3	F.	136,200
		2 4/12	M.	0
	Average....			154,400
Cocle	17	45	M.	5,200
		48	F.	82,000
		26	M.	6,000
		20	F.	11,800
		16	F.	27,000
		14	F.	44,800
		10	M.	6,900
		5	M.	356,200
		3 1/2	M.	56,600
		1 1/2	M.	89,400
	Average....			68,590
Chorrerita	28	22	M.	54,400
		17	F.	200
		55	F.	26,200
		5	M.	58,600
		1 5/12	M.	122,800
	Average....			52,440

TABLE 4 (*Continued*).

Area.	House no.	Age.	Sex.	Ascaris egg count per c.c.
Chorrerita	63	65	F.	0
		24	F.	35,400
		19	F.	59,600
		9	F.	200
		7	M.	142,400
		7	M.	40,800
		1 8/12	M.	301,200
	Average....			82,800
El Coco	33	8	F.	177,600
		32	M.	24,600
		25	F.	10,600
		5	F.	235,400
		2	F.	47,200
	Average....			99,080
Sardina	5	39	M.	14,200
		38	F.	29,000
		13	M.	70,700
		8	M.	5,000
		1 1/2	F.	144,800
	Average....			52,740
Sardina	6	35	M.	14,400
		25	F.	64,400
		12	F.	68,500
		9	M.	107,900
		5	M.	71,800
		1 1/2	F.	391,400
	Average....			119,730
Sardina	17A	32	M.	14,600
		38	F.	37,200
		16	F.	53,600
		14	F.	247,700
		9	F.	9,800
		5	M.	61,600
		4	F.	73,400
		1	M.	311,200
		24	F.	2,000
	Average....			90,120

TABLE 4 (*Continued*).

Area.	House no.	Age.	Sex.	Ascaris egg count per c.c.
Sardina	26	45	F.	24,400
		28	M.	11,400
		8	M.	8,200
		5	M.	95,200
		3	M.	109,400
		2	F.	21,600
	Average			45,030
Marica Arriba	11	40	M.	5,200
		35	F.	43,800
		20	M.	52,800
		16	F.	73,400
		13	M.	11,200
		12	F.	61,000
		8	M.	37,800
		6	M.	13,700
		5	F.	125,900
		3	F.	18,900
		1 3/12	F.	14,400
	Average			41,650
Marica Arriba	12	29	M.	0
		27	F.	34,200
		10	F.	55,800
		6	M.	81,500
		3	F.	61,000
		1 3/12	M.	12,200
	Average			40,780
La Soledad	5	42	M.	0
		36	F.	1,800
		19	M.	0
		17	M.	200
		15	M.	200
		12	F.	31,800
		10	F.	19,000
		5	F.	64,600
		6	M.	0
		4	M.	142,800
		1 1/2	M.	31,200
	Average			26,510

TABLE 4 (*Continued*).

Area.	House no.	Age.	Sex.	Ascaris egg count per c.c.
La Soledad	8	36	M.	0
		24	F.	301,000
		10	M.	500
		7	F.	0
		4	F.	51,200
		2	F.	2,700
	Average			59,230
La Atalaya	50	38	M.	0
		36	F.	3,600
		16	F.	0
		10	F.	51,600
		7	F.	218,400
		4	F.	93,600
		1	M.	2,700
		58	M.	600
	Average			46,310
Santiago	7	30	F.	17,800
		10	M.	42,900
		7	M.	48,400
		5	M.	216,600
		11/12	M.	2,600
	Average			65,660
Santiago	13	15	F.	64,500
		8	F.	180,900
		5	M.	107,400
		48	F.	0
		17	F.	65,100
	Average			83,580
Santiago	316	40	F.	22,100
		13	F.	73,000
		8	F.	200
		4	M.	153,000
		3	F.	200
	Average			49,700

TABLE 4 (*Continued*).

Area.	House no.	Age.	Sex.	Ascaris egg count per c.c.
Santiago	14	53	F.	36,300
		33	F.	2,400
		16	F.	88,400
		11	F.	52,400
		6	F.	75,600
		3	M.	83,700
		3	M.	106,400
		93	M.	0
	Average....			55,650
Santiago	16	38	M.	21,400
		36	F.	56,700
		17	F.	37,600
		10	F.	86,200
		7	F.	63,400
		14	M.	200
		2	M.	54,600
	Average....			47,160
Santiago	25	30	F.	0
		14	M.	4,500
		11	F.	50,200
		10	F.	362,400
		9	M.	19,800
		6	F.	0
		4	F.	0
		1	M.	3,000
	Average....			54,990

one of our eleven population units was adequately represented. The first striking thing that comes out of this series was that regardless of the conditions in the population group represented there was a tendency for the concentration of heavy ascaris cases in a few families. In other words certain families in every one of the areas included in our study had ascaris infestations which were extraordinarily heavy as compared with the rest of the population. Table 4 gives a series of such families. The consideration of these families again emphasizes the point, which was earlier mentioned that a very high percentage of the ascaris worm burden of the population is concentrated in Panama in a comparatively few individuals. While as suggested by these families there appeared to be a tendency for heavy ascaris infestation to spread through a whole family it should be noted that

light cases or negatives are present in almost all of these heavily infested families. It is also true that in a number of families where most of the members had very little ascaris there were found one or two extremely heavy cases. Several families might be mentioned as examples of this situation. In house 3 in Garicin we have an egg count record of 591,200 eggs per c.c. in a child 15 months old while in the other six members of the household there are four negatives and two light cases. Another such family lived in house 25 in Sardina, where a boy 7 years of age had an infestation of 106,000 eggs per c.c. while in the rest of the family there were five negatives and two light cases. In house 5 in La Atalaya a woman 55 years of age had an infestation of 234,600 eggs per c.c. while four other members of the family were negative and one lightly infested. Another house in La Atalaya contained an eleven year old girl with a count of 415,500 eggs per c.c. living with three negatives and one light case. While these cases are the most striking examples of this situation others might be added illustrating the same point. We have no specific information on these families which makes it possible to explain how the heavy infestation was acquired in the single individual or why it had not spread more to the other members of the family.

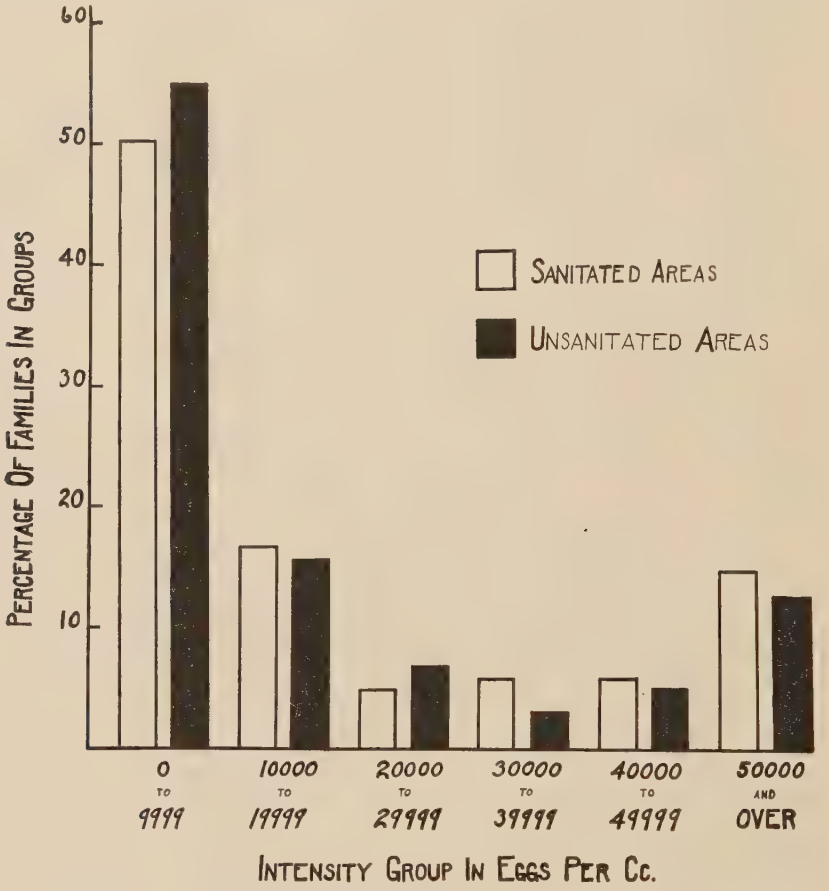
Unfortunately the conditions of our work were such that we did not make intensive studies in any considerable number of these homes of the conditions under which the most heavily infested families lived. Such studies were made, however, in a few cases by Brown (1927*a*, Table 1) who lists several very heavily infested houses in the series of which he made soil examinations. He was able to isolate ascaris eggs containing motile embryos from sweepings from the floors of these houses, and found that eggs deposited under the same conditions as those of the floors developed to the infective stage in 14 days. These findings suggested that the heavy infestations in these families were built up from pollution in the yards and within the houses themselves.

A further consideration of the heavy family infestations listed in Table 4 shows that all the areas studied are represented. At some of these houses latrines were present and in use by at least some of the family.

Contrasting with the families listed in Table 4 is a much larger number in which the infestations with ascaris are extremely light. There were in the 161 families included in this analysis 7 in which all the members were negative for ascaris. There is a much larger number in which all are negative except one or two light cases and also

another considerable series with several positives per family all of which had very light infestations. Such families in which the ascaris infestation is entirely negligible are found in every group of our Panama series. The houses in which such families live are in many cases without latrines and are in fact found as frequently in the unsanitated as in the sanitated areas.

To get a more definite conception of the distribution of ascaris infestations according to families the average egg count of each



GRAPH 2. An analysis into intensity groups of the average ascaris egg count of the 161 selected families of the Panama series. The number of families with an average egg count in each intensity group is given separately for the sanitated (Penonome, Rio Grande, Garicin, Santiago and La Atalaya) and for the unsanitated areas (Chorrerita, El Coco, Cocle, Sardina, Marica Arriba and La Soledad) on a percentage basis.

of these 161 families was taken by dividing the total number of eggs by the number in the family examined, both positives and negatives. These averages are then distributed into 6 intensity groups running in size from the lightest with an average count of between 0–999 to the heaviest group with an average of 50,000 per c.c. and over. The results of this analysis is shown in Graph 2. The consideration of this graph emphasizes certain points already brought out by the other analyses. In the first place it shows that in this large series of representative families more than half have an average infestation which would be estimated as probably less than 10 worms per member, indicating that in more than half the families of the type represented in this series both with and without latrines the conditions are unfavorable for the building up of a considerable ascaris infestation. On the other hand at the other end of the scale there is a small number of families both in the sanitated and unsanitated areas where the conditions are such that extremely heavy ascaris infestations are built up.

3. *Comparison of the ascaris infestation of the coastal plains with that of the upland region.*

The areas of Panama included in our study where no control work had been done were of two general types. Chorrerita, El Coco and Cocle were on the coastal plains where the rainfall was about 60 inches a year and where the vegetation near the houses and on the plains themselves was quite sparse. Areas of heavier rainfall with much denser vegetation especially near the houses and in the yards were represented by Sardina, Marica Arriba and La Soledad. In all of these groups as described in earlier sections soil pollution was usually present wherever there was cover within reasonable distances of the houses, and also scattered stools usually from children were often found in the open usually outside the yards. It will be recalled from the earlier sections that the upland areas had a much heavier hookworm infestation than those of the coastal plains, which we interpreted to be due to the greater rainfall and the concentration of more vegetation near the houses. A comparison of the ascaris egg counts from Chorrerita, El Coco and Cocle with those from Sardina, Marica Arriba and La Soledad (Tables 5 and 6) show that these unsanitated areas with greater rainfall and denser vegetation have a heavier ascaris infestation than those of the coastal plains. It is doubtful, however, if these differences can be interpreted as indicating any appreciable differences in the favorableness of the two types of

situations for the dissemination of ascaris. When in addition two other coastal plain areas, Rio Grande and Garicin, are included in the comparison, it is found that they have a much heavier ascaris infestation than either of the other two. These two places differ

TABLE 5.

Comparison of ascaris infestations in the different groups in Panama.

Age groups.	Penonome.				Santiago.			
	Males.		Females.		Males.		Females.	
	No. cases.	Average egg count.	No. cases.	Average egg count.	No. cases.	Average egg count.	No. cases.	Average egg count.
0–4	50	9,470	43	20,670	24	65,470	17	66,040
5–14	119	14,830	117	26,630	39	41,280	41	46,000
15+	95	8,990	147	6,170	22	9,220	89	13,790
Total	264	11,710	307	16,000	85	39,810	147	28,820
Corrected average		10,650		15,420		27,410		30,550

	Chorrerita, El Coco and Cocle.				Rio Grande and Garicin.			
0–4	44	39,450	34	5,180	32	11,690	42	58,770
5–14	57	21,350	73	26,920	52	28,280	49	56,780
15+	122	5,120	137	7,480	77	5,000	103	13,820
Total	223	16,040	244	12,970	161	13,850	194	34,400
Corrected average		9,310		12,100		12,430		31,870

	Sardina, Marica Arriba and La Soledad.				La Atalaya.			
0–4	33	41,360	40	36,550	18	7,510	12	13,220
5–14	61	16,230	48	25,150	38	13,350	36	23,830
15+	122	3,920	90	15,890	47	2,390	77	5,800
Total	216	13,120	178	23,030	103	7,330	125	11,700
Corrected average		13,590		21,660		6,220		11,630

from the other villages of the coastal plain in having a fair degree of sanitation. Their very high average infestation is produced chiefly by the presence of an unusually large number of the heavily infested

families including a number of very heavy cases. These two comparisons would seem to indicate that the upland situation with its heavier rainfall and denser vegetation did not give conditions more

TABLE 6.

Ascaris infestation of different areas in the Panama series arranged according to intensity groups.

Intensity groups in eggs per c.c.	Penonome.				Santiago.				Chorrerita, El Coco and Cocle.			
	Males.		Females.		Males.		Females.		Males.		Females.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Negative	136	51.5	164	53.4	22	25.9	51	34.7	115	51.6	123	50.4
1–9,999	55	20.8	64	20.8	23	27.1	37	25.2	56	25.1	57	23.4
10,000–49,999	54	20.4	46	15.0	23	27.1	34	23.1	29	13.0	46	18.9
50,000–99,999	13	4.9	20	6.5	7	8.2	16	10.9	14	6.3	9	3.7
100,000+	6	2.3	13	4.2	10	11.8	9	6.1	9	4.0	9	3.7
Total	264		307		85		147		223		244	

	Rio Grande and Garicin.				Sardina, Marica Arriba and La Soledad.				La Atalaya.			
Negative	81	50.3	90	46.4	102	47.2	79	44.4	62	60.2	76	60.8
1–9,999	43	26.7	37	19.1	59	27.3	41	23.0	24	23.3	34	27.2
10,000–49,999	28	17.4	38	19.6	37	17.1	29	16.3	12	11.7	8	6.4
50,000–99,999	6	3.7	10	5.1	10	4.6	19	10.7	5	4.8	4	3.2
100,000+	3	1.9	19	9.8	8	3.7	10	5.6	0	0	3	2.4
Total	161		194		216		178		103		125	

favorable for the spread of ascaris than did those of the coastal plains.

4. *Effect of the hookworm control work on the intensity of ascaris infestation.*

It is of interest to see whether in the areas where the hookworm control work had reduced the level of infestation with hookworms, it had at the same time produced a similar effect on ascaris. Since the drug of choice in Panama has been for a number of years oil of chenopodium, which is the best anthelminthic known for human ascaris, it is evident that wherever treatments were given large numbers of ascarids would be removed. That this was universally

true is shown by the reports of finding large numbers of ascarids in the stools of patients after treatment. In fact the enthusiasm for taking the treatments depended to a considerable extent in many places on the reports of the large numbers of the round worms passed especially by the children. Table 7 gives the comparison of the

TABLE 7.

Comparison of treated and non-treated individuals of two areas in Panama for average ascaris infestation.

(Males and females over 9 years of age are included.)

Areas.	Treated.		Nontreated.	
	No. of cases.	Average egg count per c.c.	No. of cases.	Average egg count per c.c.
Penonome	125	11,320	123	12,220
Rio Grande and Garicin	73	13,530	140	10,120

average egg counts for ascaris in treated and non-treated individuals in certain places where our analyses of Section VI appeared to show an effect of the treatments on the hookworm level. Other groups as for example Santiago and El Coco were also considered in this comparison and there too the average ascaris infestation was never significantly lower in the treated than the non-treated groups. We can conclude, therefore, that under the conditions of partial treatments of our areas, the reduction in the ascaris infestation produced at the time of treatment was all made up for by reinfection within a period of three years. It is probable that the return to the original level will be found to be even more rapid on account of the long life of the embryonated eggs of ascaris in the soil.

Our analyses also show that the type of sanitary work which had been carried out in the areas we studied was not effective in reducing the level of ascaris infestation. In La Atalaya only was a lower average infestation found in the people living under sanitated conditions as compared with those who were living under unsanitated conditions. Here the 98 people from the unsanitated houses had an average egg count of 12,080 eggs per c.c. and the 130 in the sanitated houses of 7,950 per c.c. While this difference may of course be due to the use of the latrines, this single case becomes of but little significance when we consider the other evidence on this point. The combined group from Rio Grande and Garicin where the great majority of houses were provided with latrines (see Section VI) shows the second

highest average egg count found in the groups listed in Table 5. While it is true that this average is greatly influenced by a series of especially heavy cases in children under 14 years of age, it is also true that the average for the adults (15 years and over) is almost twice as high as that for the adults of the comparable Chorrerita-El Coco-Cocle combined group where there is no sanitation. It is also significant that some of these heaviest cases were in houses with latrines reported in use. In this connection it will be recalled that it was shown earlier in this discussion (Graph 2) that as large a proportion of families with low average infestation were found in the unsanitated as in the sanitated areas, and that the proportion of heavily infested families was just as high in the sanitated as in the unsanitated groups. It was also stressed there that some of the very heavily infested families had latrines which were used by at least a part of the family.

The most striking situations with regard to ascaris in sanitated communities are to be found in the towns of Penonome and Santiago. It will be seen from Tables 5 and 6 that the group examined from Penonome had a higher average infestation and as high a percentage of heavy cases as that from Chorrerita, El Coco and Cocle. This seems very surprising when we consider that over 90 per cent. of the houses in Penonome had latrines in use and that there was no sanitation whatever in the other places.

Our examinations from Santiago which was also well sanitated (see Section VI) are a still more striking example of the same situation. Here the average infestation in both males and females and in every age group is very high (Table 5). When the divisions into intensity groups is considered (Table 6) it is seen that the incidence is very much higher than in any of the other areas and that the percentage of cases in the higher intensity groups is considerably greater.

5. *Ascaris infestation in towns as compared with rural districts.*

The comparison of the ascaris infestation in Santiago and Penonome with that of rural communities in the same region (Tables 5 and 6) indicates that the conditions in the poorer sections of the towns in the interior of Panama are very favorable for the spread of this parasite. It seems probable that ascariasis in Panama must be considered even more an urban than a rural problem and that we would expect to find heavy ascaris infestation widely prevalent in the cities and towns of this country.

C. Analysis of the Panama egg count data for *Trichuris trichiura*.

1. *Trichuris incidence, degree of infestation and age and sex distribution in the total series.*

The same series of egg counts as for hookworm and ascaris from the eleven population groups already described was available for the study of infestation in Panama with *Trichuris trichiura*. Of the total series of 2,247 cases on which examinations were made by the dilution egg-counting method 1,209 or 53.8 per cent. were positive for trichuris. The number of positives in the 1,052 males was 557 (52.9 per cent.) and in the 1,195 females it was 652 (54.6 per cent.). As can be seen

TABLE 8.

Analysis of total series of trichuris counts for Panama into intensity groups.

Males.

Intensity groups in eggs per c.c.*	0–9		10–19		20–39		40+		Total.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Negative	130	64.7	95	26.0	176	51.8	94	64.8	495	47.1
1–999	33	16.4	121	33.1	129	37.9	35	24.1	318	30.2
1,000–2,499	19	9.4	68	18.6	26	7.6	16	11.0	129	12.3
2,500–4,999	11	5.5	39	10.6	9	2.6	0	0	59	5.6
5,000+	8	4.0	43	11.7	0	0	0	0	51	4.8
Total	201		366		340		145		1,052	

Females.

Negative	112	59.6	112	30.8	197	44.9	122	59.8	543	45.4
1–999	43	22.9	129	35.4	157	35.8	63	30.9	392	32.8
1,000–2,499	15	8.0	55	15.1	56	12.7	15	7.4	141	11.8
2,500–4,999	8	4.3	34	9.3	14	3.2	4	2.0	60	5.0
5,000+	10	5.3	34	9.3	15	3.4	0	0	59	4.9
Total	188		364		439		204		1,195	

* As in the case of ascaris these intensity groups are merely arbitrary divisions which are used for convenience. We do not have available information which makes it possible to estimate the numbers of worms corresponding to the different groups.

from Table 8 the incidence in both males and females is lowest in children under 5 years of age and in adults over 40 years and is highest

in the children of school age (5–14 years). The average egg count of the total series of cases corrected for age and sex against the standard Porto Rican distribution (see Section IV) is 930 eggs per c.c. The corrected average counts for the males and females are about the same (Table 9). In the age groups from 15 to 39 years of age, however,

TABLE 9.

Average egg count per c.c. for trichuris infestations in Panama according to age and sex.

Age groups.	Males.		Females.	
	No. of cases.	Average egg count per c.c.	No. of cases.	Average egg count per c.c.
0–2	98	460	89	280
3–4	103	1,340	99	1,570
5–7	125	2,600	114	1,990
8–9	84	2,200	92	2,410
10–11	69	2,200	68	1,820
12–14	88	1,520	90	1,140
15–17	75	530	77	1,280
18–19	35	680	47	820
20–24	57	390	97	420
25–29	66	160	62	590
30–34	55	260	77	1,100
35–39	52	260	79	710
40–44	42	290	49	270
45–49	24	170	49	360
50–54	30	350	33	300
55–59	15	170	26	210
60+	34	250	47	360
Total	1,052	1,080	1,195	1,070
Corrected average		930		970

the average infestation in the females is over twice as high as in the males (Table 10*a* and Graph 3*a*).

Trichuris infestation is particularly heavy in children of school age (Tables 9 and 10). In the males there is a marked reduction after 14 years of age while in the females the drop comes three or four years later.*

As was found to be the case with ascaris a comparatively few heavy cases very greatly influence the averages. There are 110 cases

* The same reductions in the counts of children as discussed earlier for ascaris would hold here for trichuris (Section III).

in our series with egg counts of 5,000 eggs per c.c. or over. As seen from Table 8, 51 of these are in males and 59 in females. These cases which make up slightly less than 5 per cent. of the total group have a

TABLE 10.

Age group analysis in Panama trichuris series (see Graphs 3a and 3b).

a. Original series of 2,247 cases.

Age groups.	Males.		Females.	
	No. of cases.	Average egg count per c.c.	No. of cases.	Average egg count per c.c.
0–4	201	910	188	960
5–14	366	2,170	364	1,860
15–39	340	370	439	810
40+	145	260	204	310

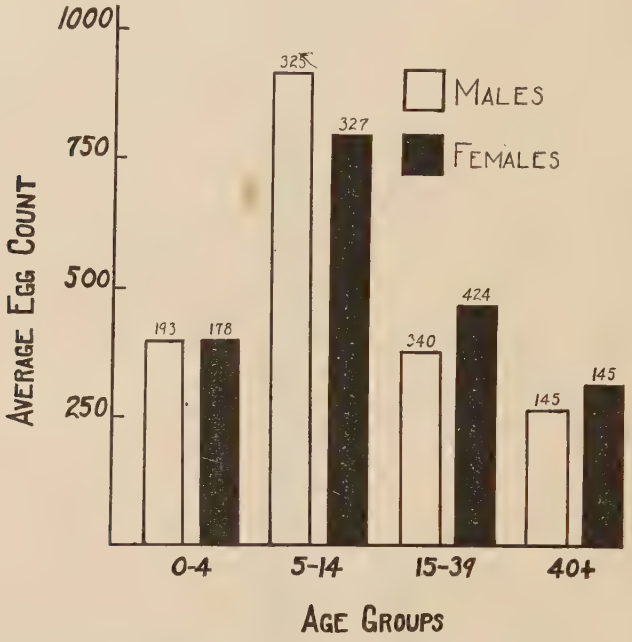
b. Series with cases of 5,000 eggs per c.c. and over removed.

0–4	193	410	178	410
5–14	325	940	327	820
15–39	340	370	424	480
40+	145	260	145	310

combined egg count of 52.6 per cent. of the total series. In other words we estimate that more than 50 per cent. of the total trichurids in this population are in less than 5 per cent. of the individuals. This is in line with what we know of trichuris infestations in general from autopsies which have been made in different parts of the world. The records of the great majority of such cases show only a few worms while occasionally cases are reported of a thousand worms or more. In the males all of the heavy cases are in children under fifteen years of age, while in the females 15 of them are in the group from 15 to 39 years of age, some occurring in every five year age group including that from 35 to 39 years. While the majority of these cases have egg counts between 5,000 and 9,999 there are 24 with counts between 10,000 and 19,999, 9 between 20,000 and 29,999, 3 between 30,000 and 39,999 and 2 over 40,000 eggs per c.c. The presence of such extremely high egg counts in our series indicates that the egg-worm ratio suggested by Moosburgger (1895) is too low, for according to his figures cases over 30,000 eggs per c.c. would have more than 9,000 worms per case which seems unlikely, although it seems possible that counts of this size may represent well over 1,000 worms. On the

GRAPH 3*a*. Comparisons of the egg counts of trichuris in the Panama series for age and sex. Original series of 2,247 cases. The numbers above the bars represent the number of cases upon which the average count is based.

other hand it would appear that the estimate of egg production by female trichurids obtained by Manalang (1928) must be too high since if his figures are used the number of worms represented by almost all of our egg counts from Panama would be so small as to be



Graph 3*b*. Comparisons of egg counts of trichuris in Panama series for age and sex. Series with case of 5,000 eggs per c.c. or over removed.

practically negligible. The relation of these heavy cases to infestation by families and by population groups will be considered in later connections. It is of interest to consider to what extent the peculiarities of the average infestations according to age and sex are influenced by these heavy cases. We have, therefore, in Table 10*b* and Graph 3*b*, set up the series with these cases removed. This analysis shows that to a very considerable extent both the higher averages in children than in adults and in the females than the males are due to the distribution of these cases.

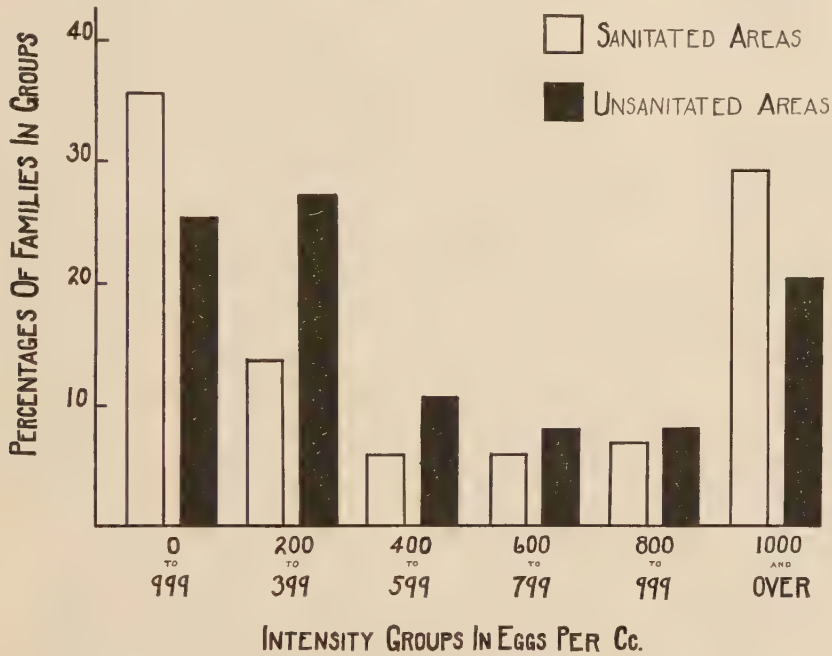
This same thing is also brought out in the analysis according to intensity groups (Table 8) which shows a considerably higher proportion of the children than the adults in the two highest intensity groups. The females in the 15 to 39 year age groups show a higher incidence than the males and a greater proportion of cases in all

three of the higher intensity groups. Another very striking point that is brought out in Table 8 is that in both males and females almost 80 per cent. of the total cases are included in the negatives and in the lowest of the intensity groups.

2. *Trichuris infestation according to family groups.*

The same series of 161 families in which the ascaris infestation was discussed is used for the analysis of trichuris according to family groups. In this case, too, there is a tendency for the concentration of the heavy cases in a few families.

These 161 families are representative of the total series and their analysis using the average infestation of each family as a unit in the same way as was done for ascaris sheds light on the distribution of the trichuris infestation in the population under consideration. Graph 4 shows the distribution of these family averages into six intensity



GRAPH 4. An analysis into intensity groups of the average trichuris egg count of the 161 selected families of the Panama series. The number of families with an average egg count in each intensity group is given separately for the sanitated (Penonome, Rio Grande, Garicin, Santiago and La Atalaya) and for the unsanitated areas (Chorrerita, El Coco, Cocle, Sardina, Marica Arriba and La Soledad) on a percentage basis.

TABLE 11.

A list of families having a high average trichuris infestation.

Area.	House no.	Age.	Sex.	Trichuris egg count per c.c.
Penonome	214	6	M.	4,200
		4	M.	2,600
		2	M.	300
		28	F.	0
		8	F.	1,800
	Average			1,780
Penonome	34	48	M.	0
		42	F.	1,000
		18	F.	8,000
		13	M.	900
		12	F.	1,000
		9	M.	600
		5	M.	600
	Average			1,730
Penonome	35	38	F.	1,000
		16	M.	600
		15	M.	100
		13	M.	200
		10	M.	2,900
		7	F.	6,400
		1 1/2	M.	2,400
		1	M.	0
		13	M.	500
	Average			1,570
Rio Grande	17	38	M.	1,200
		30	F.	1,600
		18	M.	1,000
		16	M.	0
		13	F.	200
		9	M.	1,600
		5	M.	1,200
		3	F.	2,400
		1 2/12	F.	0
	Average			1,020
Rio Grande	63	21	M.	0
		35	F.	2,300
		19	F.	0
		17	F.	0
		15	F.	1,500
		13	M.	1,200
		9	F.	1,200
		23	F.	0
		3	F.	3,600
		1 1/2	M.	0
		18	M.	2,400
	Average			1,110

TABLE 11 (*Continued*).

Area.	House no.	Age.	Sex.	Trichuris egg count per c.c.
Garicin	40	48	M.	200
		19	F.	500
		16	F.	1,600
		11	M.	1,700
		6	F.	2,800
		6/12	M.	0
	Average....			1,130
Cocle	17	45	M.	0
		48	F.	600
		26	M.	0
		20	F.	0
		16	F.	900
		14	F.	200
		10	M.	900
		5	M.	8,800
		3 1/2	M.	200
		1 1/2	M.	0
	Average....			1,160
Chorrerita	16	60	M.	1,000
		45	F.	0
		15	F.	4,800
		13	F.	200
		1 3/12	M.	0
		30	F.	1,800
		9	F.	900
	Average....			1,240
Chorrerita	18	38	F.	600
		15	M.	400
		11	F.	6,200
		6	M.	6,400
		5	M.	4,200
		3	M.	1,000
		4/12	F.	0
	Average....			2,690
Chorrerita	28	22	M.	200
		17	F.	5,600
		55	F.	600
		5	M.	0
		1 5/12	M.	400
	Average....			1,360

TABLE 11 (*Continued*).

Area.	House no.	Age.	Sex.	Trichuris egg count per c.c.
Chorrerita	55	40	M.	0
		21	F.	400
		4	M.	600
		2	M.	200
		4	M.	0
		7	F.	3,600
		34	F.	3,200
	Average....			1,140
Chorrerita	63	65	F.	0
		24	F.	0
		19	F.	400
		9	F.	1,800
		7	M.	4,600
		7	M.	1,600
		1 8/12	M.	2,000
	Average....			1,490
El Coco	33	8	F.	3,400
		32	M.	1,800
		25	F.	800
		5	F.	4,200
		2	F.	1,800
	Average....			2,400
Sardina	21	20	M.	700
		22	F.	0
		7	F.	3,000
		4	M.	2,000
		3	M.	3,400
		2	M.	0
		9/12	F.	0
	Average....			1,300
Sardina	26	45	F.	600
		28	M.	1,400
		8	M.	2,400
		5	M.	5,600
		3	M.	13,800
		2	F.	1,800
	Average....			4,270

TABLE 11 (*Continued*).

Area.	House no.	Age.	Sex.	Trichuris egg count per c.c.
Marica Arriba	14	38	M.	600
		36	F.	0
		13	F.	800
		11	M.	1,400
		6	M.	2,400
	Average			1,040
Marica Arriba	11	40	M.	1,400
		35	F.	200
		20	M.	800
		16	F.	3,200
		13	M.	2,000
		12	F.	4,000
		8	M.	2,100
		6	M.	800
		5	F.	4,100
		3	F.	2,300
		1 3/12	F.	800
	Average			1,970
La Soledad	5	42	M.	0
		36	F.	300
		19	M.	200
		17	M.	200
		15	M.	0
		12	F.	1,400
		10	F.	500
		5	F.	1,000
		6	M.	2,500
		4	M.	8,100
		1 1/2	M.	0
	Average			1,290
La Soledad	8	36	M.	0
		24	F.	1,200
		10	M.	2,700
		7	F.	8,900
		4	F.	7,200
		2	F.	4,200
	Average			4,030

TABLE 11 (*Continued*).

Area.	House no.	Age.	Sex.	Trichuris egg count per c.c.
La Soledad	17	43	M.	0
		39	F.	700
		18	F.	500
		16	M.	900
		14	M.	1,000
		7	F.	8,100
		5	M.	2,700
		2	F.	3,200
	Average....			2,140
La Soledad	25	58	M.	600
		19	M.	300
		17	F.	0
		10	M.	3,900
		14	M.	1,400
	Average....			1,240
La Soledad	34	42	M.	1,500
		32	F.	200
		11	F.	500
		9	M.	900
		6	M.	6,300
		5	M.	17,800
	Average....			4,530
La Atalaya	10	40	F.	0
		22	M.	0
		15	F.	600
		13	M.	4,800
		9	F.	20,200
		9	M.	2,800
		8	F.	8,600
		18	M.	600
		1	F.	0
	Average....			4,180
La Atalaya	16	10	M.	29,100
		8	M.	11,600
		6	M.	2,000
		6	M.	6,000
		14	M.	8,400
		8	F.	0
		71	F.	600
	Average....			8,240

TABLE 11 (*Continued*).

Area.	House no.	Age.	Sex.	Trichuris egg count per c.c.
Santiago	7	30	F.	1,600
		10	M.	7,100
		7	M.	4,200
		5	M.	7,700
		11/12	M.	0
	Average....			4,120
Santiago	13	15	F.	600
		8	F.	9,300
		5	M.	2,600
		48	F.	400
		17	F.	1,200
	Average....			2,820
Santiago	14	53	F.	1,100
		33	F.	3,200
		16	F.	1,600
		11	F.	800
		6	F.	400
		3	M.	0
		3	M.	400
		93	M.	0
	Average....			1,390
Santiago	16	38	M.	1,200
		36	F.	1,400
		17	F.	600
		10	F.	5,600
		7	F.	9,800
		14	M.	5,700
		2	M.	4,600
	Average....			4,130
Santiago	17	38	F.	1,400
		10	M.	3,600
		7	M.	5,400
		8	F.	7,000
		5	M.	15,800
	Average....			6,640
Santiago	23	60	F.	2,400
		23	F.	1,400
		18	M.	0
		33	F.	1,200
		16	M.	3,800
		9	M.	400
	Average....			1,530

TABLE 11 (*Continued*).

Area.	House no.	Age.	Sex.	Trichuris egg count per c.c.
Santiago	24	43	M.	1,100
		25	F.	8,700
		45	F.	800
		15	M.	3,200
		9	F.	41,000
		7	M.	10,800
		5	M.	25,200
		3	F.	20,700
		1	F.	4,400
	Average....			12,880
Santiago	25	30	F.	37,600
		14	M.	13,100
		11	F.	5,400
		10	F.	23,200
		9	M.	29,800
		6	F.	14,400
		4	F.	9,000
		1	M.	4,200
	Average....			17,090
Santiago	45	55	F.	1,800
		39	F.	3,000
		22	F.	400
		11	F.	2,200
		34	F.	0
		1	F.	100
	Average....			1,250
Santiago	30	65	F.	3,900
		61	F.	2,800
		63	M.	0
		33	F.	3,900
		11	F.	8,500
		8	F.	17,600
		6	F.	9,800
		4	M.	11,800
		18	M.	3,800
	Average....			6,900

TABLE 11 (*Continued*).

Area.	House no.	Age.	Sex.	Trichuris egg count per c.c.
Santiago	325	52	M.	2,400
		22	F.	800
		30	M.	300
		33	F.	100
		11	M.	7,500
		10	F.	4,800
		1 1/2	M.	0
		9	F.	600
		6	M.	800
		29	F.	0
	Average....			1,730
Santiago	322	54	F.	900
		16	M.	1,400
		3	M.	18,000
		7	F.	17,600
		19	F.	800
	Average....			7,750
Santiago	314	35	F.	2,800
		15	F.	5,700
		5	F.	3,500
		9	F.	4,200
		2	M.	2,800
	Average....			3,800
Santiago	316	40	F.	2,000
		13	F.	7,600
		8	F.	3,800
		4	M.	25,800
		3	F.	600
	Average....			7,960
Santiago	289	41	M.	2,100
		35	F.	1,100
		15	F.	28,200
		13	M.	18,600
		8	F.	18,900
		6	F.	7,800
		2	M.	1,600
	Average....			11,190
Santiago	290	38	M.	0
		23	F.	400
		8	F.	1,200
		3	F.	8,800
		1 1/2	F.	0
	Average....			2,080

TABLE 11 (*Continued*).

Area.	House no.	Age.	Sex.	Trichuris egg count per c.c.
Santiago	24	43	M.	1,100
		25	F.	8,700
		45	F.	800
		15	M.	3,200
		9	F.	41,000
		7	M.	10,800
		5	M.	25,200
		3	F.	20,700
		1	F.	4,400
	Average....			12,880
Santiago	25	30	F.	37,600
		14	M.	13,100
		11	F.	5,400
		10	F.	23,200
		9	M.	29,800
		6	F.	14,400
		4	F.	9,000
		1	M.	4,200
	Average....			17,090
Santiago	45	55	F.	1,800
		39	F.	3,000
		22	F.	400
		11	F.	2,200
		34	F.	0
		1	F.	100
	Average....			1,250
Santiago	30	65	F.	3,900
		61	F.	2,800
		63	M.	0
		33	F.	3,900
		11	F.	8,500
		8	F.	17,600
		6	F.	9,800
		4	M.	11,800
		18	M.	3,800
	Average....			6,900

TABLE 11 (*Continued*).

Area.	House no.	Age.	Sex.	Trichuris egg count per c.c.
Santiago	325	52	M.	2,400
		22	F.	800
		30	M.	300
		33	F.	100
		11	M.	7,500
		10	F.	4,800
		1 1/2	M.	0
		9	F.	600
		6	M.	800
		29	F.	0
	Average....			1,730
Santiago	322	54	F.	900
		16	M.	1,400
		3	M.	18,000
		7	F.	17,600
		19	F.	800
	Average....			7,750
Santiago	314	35	F.	2,800
		15	F.	5,700
		5	F.	3,500
		9	F.	4,200
		2	M.	2,800
	Average....			3,800
Santiago	316	40	F.	2,000
		13	F.	7,600
		8	F.	3,800
		4	M.	25,800
		3	F.	600
	Average....			7,960
Santiago	289	41	M.	2,100
		35	F.	1,100
		15	F.	28,200
		13	M.	18,600
		8	F.	18,900
		6	F.	7,800
		2	M.	1,600
	Average....			11,190
Santiago	290	38	M.	0
		23	F.	400
		8	F.	1,200
		3	F.	8,800
		1 1/2	F.	0
	Average....			2,080

groups ranging between the lowest with an average infestation of between 0 and 199 eggs per c.c. to those over 1,000.

This graph shows a tendency for the families to be concentrated either into those very lightly infested or into the highest intensity group. The families with the heaviest average infestation are listed in Table 11. Such families are found in every area, but their number is especially large in Santiago where sixteen of the forty are found. Here, too, the average family infestations are very high and a surprisingly large proportion of the heaviest cases are found. Further discussion of the extraordinarily high infestation of Santiago is given below. These heavily infested families are found in both sanitated and unsanitated groups. Next to Santiago, La Soledad had the largest number of heavily infested families, although here the average infestation per family is not so high. Three of these families live in Rio Grande and Garicin in houses with latrines which were reported to be in use. It should be noted that the family in house 16 in La Atalaya really belongs to the Santiago series since they had moved to this place from Santiago only three months before. It is also of interest that the other house from La Atalaya in this series, number 10, was on the central square and had a latrine in use.

It is quite noticeable also that except in Santiago there is a tendency for the adults in these heavily infested families either to be negative or to have light infestations. Also the very youngest children tend to be negative or to have low counts.

Contrasted with these heavily infested families listed in Table 11, there is a larger series in which the infestations with trichuris are extremely light. Eleven families of the 161 are recorded as being entirely negative for trichuris and 17 more were entirely negative except for one very light case. Another group of families was negative except for two or three light cases each. Such families with negligible infestations are found in every group except Santiago, and are as numerous in unsanitated as in the sanitated areas.

3. *Comparison of trichuris infestation in the coastal plains and the uplands.*

As with ascaris it is of interest to compare for trichuris the upland areas which have such heavy hookworm infestation with the coastal plains area where the conditions are not so favorable for the spread of this parasite. It can be seen from Tables 12 and 13 that the upland area represented by Sardina, Marica Arriba and La Soledad with its heavier rainfall and denser vegetation has about the same average

infestation as the coastal plains area represented by Chorrerita, El Coco and Cocle. This suggests that the differences in these areas in rainfall and vegetation are not critical factors in trichuris dissemination.

4. *Trichuris infestation in urban and rural groups.*

One of the most striking things in our whole analysis of the trichuris egg counts is the extremely high level of infestation found in the towns of Santiago and Penonome as compared with the rural areas of the same region (Tables 12 and 13). Santiago especially when

TABLE 12.

Comparison of the average egg counts per c.c. for trichuris in different groups in Panama.

Age groups.	Penonome.				Santiago.			
	Males.		Females.		Males.		Females.	
	No. cases.	Average egg count.	No. cases.	Average egg count.	No. cases.	Average egg count.	No. cases.	Average egg count.
0–4.....	50	380	43	540	24	4,230	17	5,030
5–14.....	119	1,770	117	1,240	39	6,160	41	7,140
15+.....	95	320	147	540	22	1,370	89	2,230
Total.....	264	990	307	810	85	4,380	147	3,920
Corrected average....		560		720		3,150		3,950

	Chorrerita, El Coco and Cocle.				Rio Grande and Garicin.			
0–4.....	44	250	34	670	32	300	42	390
5–14.....	57	1,780	73	1,520	52	490	49	510
15+.....	122	270	137	440	77	330	103	340
Total.....	223	650	244	800	161	380	194	390
Corrected average....		680		760		320		390

	Sardina, Marica Arriba and La Soledad.				La Atalaya.			
0–4.....	33	1,150	40	750	18	200	12	150
5–14.....	61	1,670	48	1,070	38	3,020	36	1,380
15+.....	122	300	90	360	47	150	77	180
Total.....	216	820	178	640	103	1,220	125	520
Corrected average....		810		600		930		480

TABLE 13.

Trichuris infestations in Panama series arranged according to intensity groups.

Intensity groups.	Penonome.				Santiago.				Chorrerita, El Coco and Cocle.			
	Males.		Females.		Males.		Females.		Males.		Females.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
Negative	111	42.0	121	39.4	17	20.0	11	7.5	118	52.9	130	53.3
1–999	94	35.6	114	37.1	10	11.8	52	35.4	70	31.4	80	32.8
1,000–2,499	28	10.6	47	15.3	15	17.6	29	19.7	25	11.2	19	7.8
2,500–4,999	21	7.9	17	5.5	21	24.7	19	12.9	5	2.2	8	3.3
5,000+	10	3.8	8	2.6	22	25.9	36	24.5	5	2.2	7	2.9
Total	264		307		85		147		223		244	

	Rio Grande and Garicin.				Sardina, Marica Arriba and La Soledad.				La Atalaya.			
Negative	97	60.2	119	61.3	89	41.2	81	45.5	63	61.2	81	64.8
1–999	40	24.8	49	25.3	81	37.5	66	37.1	23	22.3	31	24.8
1,000–2,499	23	14.3	20	10.3	30	13.9	18	10.1	8	7.8	8	6.4
2,500–4,999	0	0	5	2.6	9	4.2	9	5.1	3	2.9	2	1.6
5,000+	1	.6	1	.5	7	3.2	4	2.2	6	5.8	3	2.4
Total	161		194		216		178		103		125	

compared with Sardina, Marica Arriba and La Soledad and with La Atalaya shows an extremely high average infestation, with a surprising concentration of heavy cases (Tables 12 and 13). In fact Santiago represents a type of trichuris infestation of an entirely different kind from any of the other areas. In this group which includes about 10 per cent. of the individuals in the series there is concentrated about 40 per cent. of all the infestation. The incidence of infection here is almost 90 per cent. and 25 per cent. of the cases have an infestation of over 5,000 eggs per c.c., which is more than 50 per cent. of such cases for the whole series.

While the conditions in Penonome are not comparable to those in Santiago in their favorableness for building up heavy trichuris infestation, it is striking that this town has the second highest average of the areas, and surpasses considerably the infestation in the nearby rural communities of Chorrerita, El Coco and Cocle and to a greater extent that of Rio Grande and Garicin. When the extent of the

sanitation in Penonome and Santiago is considered, the conclusion is inevitable that by far the most favorable environment for the spread of trichuris in Panama is to be found in the poorer sections of the towns of the interior.

5. *Effect of the hookworm control work on the level of trichuris infestation in Panama.*

It is perfectly evident from the situation in Penonome and Santiago that under the conditions of the poorer sections of the towns the hookworm control work was not effective for the control of trichuris. La Atalaya and the combined villages of Rio Grande and Garicin should also be considered in this connection. In the La Atalaya group one family from Santiago which had moved there three months before and which had a trichuris infestation of the type characteristic of Santiago greatly influenced the average. With this family of five removed the average becomes 600 eggs per c.c. which is a little below the unsanitated rural areas. It is interesting also that Rio Grande and Garicin (Tables 12 and 13) have the lowest average infestation of any of the groups. The incidence in these places is only slightly over 40 per cent. and the number of cases in the two higher infestation groups is much fewer than in any of the other areas. That this low trichuris infestation is due to the sanitation is hard to believe when we consider that it is in these same two villages that the highest average ascaris infestation of all the areas except Santiago is found. We have no explanation to offer of the factors producing the differences between the intensity of infestation with these two parasites in this area. It has already been noted that some of the families with the heaviest trichuris infestation live in houses which had latrines in use. It would seem from the facts enumerated above that the type of sanitation which has been developed in the parts of Panama where we made our study was not effective in preventing the spread of trichuris.

D. A comparison of the factors determining the distribution of ascaris, trichuris and hookworm in Panama.

1. *General considerations.*

While an enormous body of statistics is available in the literature on the incidence of *Ascaris lumbricoides* and *Trichuris trichiura* in different parts of the world, there is comparatively little information which makes it possible to understand the particular factors influencing the distribution of these parasites in different places. We will not

attempt at this time to consider the distribution of ascaris and trichuris as world problems or to sift out the widely scattered information which relates to the methods of their dissemination. The analysis of the egg counts for these parasites in Panama just given makes it possible to shed light on certain factors which influence their etiology in that country. In this summary we will attempt to bring together some of the evidence on these factors by comparing the distribution of ascaris, trichuris and hookworm for our Panama series by age and sex, by families and by groups which are known to differ in certain definite respects.

2. *Comparisons of incidence, intensity of infestation and age and sex distribution of ascaris, trichuris and hookworm in the total series.*

In our whole group the incidence of both ascaris and trichuris was about 50 per cent. The large proportion of negative cases for both ascaris and trichuris is in very clear cut contrast with the incidence of hookworm in the Panama groups which ranges around 90 per cent. This same difference is present in most of the population groups for which there are available in the literature figures on the comparative incidence of these three parasites and is the first indication that we have that the factors determining the distribution of ascaris and trichuris are not so general and are more strictly limited in their influence than those for hookworm. Of similar significance is the fact that in both ascaris and trichuris about 50 per cent. of the total worm burden is concentrated in about 5 per cent. of the group, while for hookworm the infestation is much more evenly distributed. Also, except in areas where a considerable amount of control work has been done, there is not nearly as large a proportion of very light cases of hookworm as for the other two parasites. These facts indicate that the combination of conditions necessary to build up heavy hookworm infestations are much more easily achieved in Panama than those necessary for the production of heavy cases of ascaris and trichuris. As noted in Section V the hookworm egg counts in Panama are the highest ever reported by quantitative methods for any place in the world. Unfortunately information is not available which makes it possible to compare quantitatively the ascaris and trichuris infestations in our series with those of other places.* There are, of course, records available of groups where the incidence of these parasites is much

* Gordon (1925) records egg counts for ascaris and trichuris in a series of 137 adult male negroes on the west coast of Africa. Most of his cases are very lightly infested and his average for both parasites is low. His highest ascaris count was 42,630 eggs per gram and his highest trichuris count was 7,800 eggs per gram.

higher than in Panama, but whether this also means a heavier worm burden we have no way of knowing.

The very heavy infestation of ascaris and trichuris in children as compared with adults is especially striking in our series even when liberal allowance is made for stool size. In ascaris, even the group under six years of age, especially in the males, has a much heavier infestation than have the adults. In the males the break comes from 8 to 11 years of age while in the females it is considerably delayed. Trichuris differs from ascaris in age distribution since the youngest children have low infestations, the highest point comes about 8 to 14 years and the reduction comes somewhat later. We have no information which makes it possible to offer any clue to the cause of this difference between ascaris and trichuris infestation in the young children. It may be that the later drop in the level for trichuris is due to greater stability and longer life of this parasite, since it is known that with ascaris there is a constant tendency for adult worms to be expelled. The adult trichurids on the other hand are for the most part attached to the wall of the caecum and appendix and are therefore much less likely to be expelled. The later reduction of the level for both these parasites in the females as compared with the males is associated with a general heavier infestation in females than in males for both parasites in early adult life. For ascaris this difference is pronounced from 10 to 40 years of age, while in trichuris it is found from 15 to 40 years.

When we consider the infestation of hookworm according to age and sex an entirely different picture is revealed. Not only in our Panama series but in most other places where quantitative studies have been made the hookworm infestation in young children is negligible as compared with the adults. The age at which the adult averages are attained varies with the local situation but usually comes somewhere between 10 and 20 years. Also for hookworm in our Panama series, as well as in most situations that have been studied elsewhere, the males have a distinctly heavier infestation than the females. This distribution of hookworm according to age and sex has been interpreted in our Panama series to mean that the adults with pollution spots at a little distance from the houses are chiefly responsible for the spread of the parasite, that the immediate environs of the houses are comparatively safe and that it is only as the children begin to assume the pollution habits of the adults that they begin to build up the adult type of infestation. We offered two possible explanations of the lower infestation of the adult females (Section V).

In the first place the males are very often engaged in agricultural work away from home which might expose them to sources of infection escaped by the females. On the other hand there were known to be numbers of females who part of the time at least did not visit the dangerous pollution spots which are almost always frequented by the adult males.

There are two possible explanations of the contrast between the age distribution of ascaris and trichuris and that of the hookworm, viz., either adults with the same exposure are less susceptible than children or the conditions of dissemination of ascaris and trichuris in Panama are quite different from those for the hookworm. It is known that for certain ascarids of lower animals there is much less susceptibility in older than in younger animals, viz., for *Ascaridia lineata* in the chick (Herrick, 1925) and apparently for the dog, cat and pig ascarids. We do not know, however, of similar information for any species of trichuris. In spite of this situation certain facts make it seem more probable that the heavy infestations of ascaris and trichuris in children in Panama as compared with the adults are due chiefly at least to conditions which bring about a greater exposure to infection. One of these facts is that the incidence of infection in adults is only slightly less than in children for both these parasites and that there are present in adults a considerable number of the heaviest cases (32 cases in persons 20 years of age or over with 50,000 eggs per c.c. or more for ascaris and 23 cases in those over 14 years of age of more than 2,500 eggs per c.c. for trichuris). These cases and the large series of heavy adult cases for both parasites found in the literature indicate that there can hardly be any considerable degree of insusceptibility in adults for either of these parasites. There is also a tendency for adults in families in which the children have especially high egg counts to also have heavy infestations.

On the basis of these facts the hypothesis can be suggested that for both ascaris and trichuris in Panama certain factors in the life of the children give them greater exposure to infection than adults, and that the children are chiefly responsible for the transmission of these parasites both to other children and to adults. The fact that for both these parasites the females from 15 to 40 years of age have a considerably higher level of infestation than the males, supports this hypothesis because this is the childbearing period during which the women are very closely associated with the young children and would be more apt to be affected by the same conditions. All these facts fit in well with the findings of Brown (1927*a*), who was able to isolate

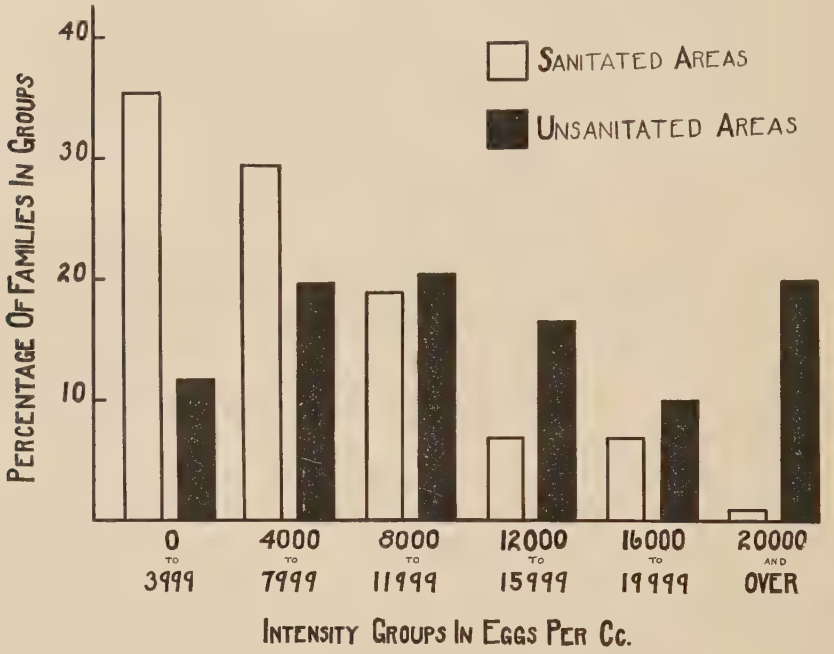
viable ascaris eggs from the floors of several Panama houses, and who concludes that ascaris was chiefly spread in these houses by the pollution of the door yard and the floor of the houses themselves by the very young children. They also fit in with our common observation that young children did not use latrines when present and deposited their stools near the houses. Other points summed up later also support this view until the conclusion seems inevitable that for the situations we studied in Panama the chief sources of ascaris and trichuris infection were eggs derived from the children, especially those of preschool age, whose defecations were not controlled and who commonly deposited their stools in the environs of the houses.

3. *Infestation with ascaris, trichuris and hookworm by families.*

The analysis of ascaris and trichuris by families brings out some interesting points. For both parasites there is a tendency for the concentration of extraordinarily heavy infestation into a comparatively few family groups. Such families were found under all the kinds of conditions represented by our series, in the coastal plains areas as well as in the uplands, in the urban groups and the rural groups and in the groups in which hookworm control work had been carried out as well as in the unsanitated communities. In fact at a number of the houses listed with very heavy infestations both of ascaris and trichuris, latrines were present and in use by part at least of the inhabitants. Contrasted with these families was a much larger series in which infestations with ascaris and trichuris were not present or were so light as to be probably entirely negligible. These houses too occurred under all the kinds of conditions represented. They were no more frequent in the sanitated than the unsanitated groups and represented a considerable proportion of the families in all the communities except Santiago, where the level of both parasites was uniformly high. From these facts two very significant points are clear, viz., that the general soil pollution coincident with the absence of a latrine was not in itself sufficient to build up significant infestations with ascaris and trichuris and the presence and use of a latrine by a family did not in itself prevent the spread of these parasites. Here again evidence points to the special conditions of sanitation and personal hygiene within and around the houses themselves and to the youngest children who can hardly ever be made to use latrines but who deposit their stools in the yards.

When the hookworm infestation is examined in this same series of

161 families the contrast with the ascaris and trichuris is at once evident. Graph 5 gives an analysis of family averages for hookworm in six intensity groups where the distribution can be compared with that given for the other two parasites (cf. Graphs 2 and 4). In the first



GRAPH 5. An analysis into intensity groups of the average hookworm egg counts of the 161 selected families of the Panama series. The number of families with an average egg count in each intensity group is given separately for the sanitated (Penonome, Rio Grande, Garicin, Santiago and La Atalaya) and for the unsanitated areas (Chorrerita, El Coco, Cocle, Sardina, Marica Arriba and La Soledad) on a percentage basis.

place an effect of the sanitation which does not appear at all in the analysis for the other two parasites is evident since in the unsanitated areas, a much larger proportion of the families have a low average hookworm infestation than in the unsanitated and the number in the highest groups is much less. This is in line with what has been noted in earlier sections on the effect of the sanitation in reducing the hookworm in Panama, and illustrates how the adequate response of certain families brings them into the group in which the infestation is of a negligible type.

Of particular interest is the comparison of hookworm, ascaris and

trichuris by families in the unsanitated areas. It is seen that for hookworm there is no such proportion of families with negligible infestations and there tends to be a much more uniform distribution into the other intensity groups. This indicates, again, that conditions favorable for hookworm dissemination are much more uniformly present, where the situation is undisturbed by control work, than for the other two parasites. These facts also fit into the views expressed already on the differences in the factors influencing the spread of these three parasites.

As would be expected from the facts already presented there was no correlation between the average hookworm egg count by families and that of ascaris and trichuris. In other words there was no tendency throughout this series of 161 family groups for heavy hookworm infestations to be associated with either heavy ascaris or heavy trichuris, nor on the other hand is there a tendency for light infestations to be associated.

From the comparisons we have given of the egg count analyses of ascaris and trichuris in Panama and from what we know of their etiology we would certainly expect a correlation between them in the series of family infestations. We, therefore, set up the average infestations by families into a correlation table and derived the coefficient of correlation. We were surprised to find that there was no valid correlation with a coefficient of 0.00876 ± 0.053. This lack of correlation was particularly evident when a series of families were considered where the average infestation with one of these parasites was very high and the other extremely low. In fact such extreme cases as those families listed in Table 14 are chiefly responsible for the extremely low coefficient of correlation, since their averages for one or the other of the parasites were so high as compared with the large majority of the averages in the correlation table. In fact when these extremely high averages for both ascaris and trichuris are removed there was a high correlation with a coefficient of correlation of 0.747 ± 0.025 between the infestations of these two parasites in the remaining 136 families in which the average ascaris infestations were not over 90,000 eggs per c.c. and the average trichuris infestations were not over 1,500 eggs per c.c. We interpret this to indicate that there is some correlation between family infestations with these two parasites. In the Santiago group there is a uniformly high infestation with both ascaris and trichuris so that there is a correlation in this group both in individual and family infestations. When we add to this the general correspondence already discussed between the distri-

bution according to age and sex which differs so strikingly from that of the hookworm, we must conclude that part of the factors influencing the distribution of ascaris and trichuris in Panama are the same.

TABLE 14.

Instances of the lack of correlation in intensity of ascaris and trichuris infestations in certain families.

Area.	House no.	No. of individuals.	Av. ascaris infestation.	Av. trichuris infestation.
Rio Grande	5	10	85,470	0
Rio Grande	9	10	15,940	0
Rio Grande	11	5	44,430	100
Rio Grande	66	6	166,720	30
Rio Grande	70	5	85,240	80
El Coco	5	6	59,600	220
La Soledad	17	8	330	2,140
La Soledad	25	5	440	1,240
La Soledad	34	6	9,470	3,890
La Atalaya	10	9	1,440	4,180
La Atalaya	76A	5	83,620	60
Santiago	24	9	4,140	11,590
Santiago	30	9	7,390	6,900
Santiago	322	5	3,080	6,450

On the other hand it also seems certain that there must be differences in their etiology which at present are not understood. Certainly there is no other explanation for the lack of correlation in the total series of family groups, the differences in the youngest children, and such striking differences as are found in Rio Grande and Garicin.

4. *Comparison of ascaris, trichuris and hookworm in the different areas studied.*

Since different groups of people were included in our Panama series representing different conditions, it is possible to obtain certain information of interest by comparing the three parasites according to population groups with known differences. In this way we can get information on the influence of climatic differences, on urban as compared with rural life and on the effect of the type of partial hookworm control work that had been carried on.

It will be remembered that the combination of conditions in the upland groups (Sardina, Marica Arriba, La Soledad and La Atalaya) produced a level of hookworm infestation about 60 per cent. higher than in the coastal plains areas where the rainfall was lower and there

was much less vegetation near the houses (Chorrerita, El Coco, Cocle, Rio Grande and Garicin). There is no evidence whatever from the comparison of the average infestations of these groups that the greater rainfall of the uplands produced conditions more favorable for the spread of ascaris and trichuris than those of the coastal plains. In fact a considerable number of the most heavily infested families are from the second type of areas. This does not necessarily mean that under certain conditions greater rainfall might not produce more favorable conditions for the spread of these parasites but suggests that in these Panama areas climatic and soil conditions are not the determining factors.

Perhaps the most striking point in our whole study is the heavy infestations of both ascaris and trichuris in the poorer sections of Santiago City as compared with all the other areas. While this is striking enough with ascaris the differences with trichuris are so great, that the Santiago group alone with only about 10 per cent. of the total cases has about 40 per cent. of the total infestation. The survey of the Santiago area (see Section VI) showed a considerable amount of soil pollution usually attributed to children, in the narrow confines of the yards, and it was concluded that while most of the adults used the latrines, a large proportion of the children especially those of the preschool age deposited their stools in the yards where the soil was well shaded and constantly moist during the long rainy season. Such yards would become thoroughly seeded with ascaris and trichuris eggs, which would also be easily carried into the houses. Here again the evidence points to the stools of the young children deposited near the houses and in some cases on the floors themselves as the source of the extraordinarily heavy infestation. The fact that the town conditions should be so much more favorable than the rural even where there was no sanitation at all, can probably be attributed to the crowded conditions which would concentrate the stools near the houses and produce the maximum exposure. Why trichuris should show comparatively much heavier infestations under these conditions as compared with ascaris is a mystery and again suggests that there are differences in the etiology of these two parasites not at present understood. The situation in Penonome also, but to a lesser extent, illustrates the particularly favorable conditions for the spread of ascaris and trichuris that can develop in the towns of Panama. Here the average infestation of the two parasites is not as high when compared with the comparable rural districts as in Santiago, but it is still striking when we consider the considerable proportion of people of the better classes included in our Penonome group.

5. *Effect of sanitation on ascaris and trichuris.*

No better example of the failure of the type of sanitation developed in Panama to limit the spread of ascaris and trichuris can be found than the situation in Santiago and Penonome just discussed where there was a larger proportion of latrines in general use than in any of the other areas we studied. The situation in these two places seems to give almost conclusive evidence that the young children are chiefly responsible for the dissemination of ascaris and trichuris. While the evidence from the comparison of the sanitated and unsanitated groups in the rural areas is not so uniform it can hardly be considered in any case to demonstrate a reduction due to the presence of latrines and the bulk of the data agree with those obtained from Santiago and Penonome. For example the heaviest average ascaris infestation except in the Santiago group is found in the Rio Grande-Garicin area in which about 90 per cent. of the houses have latrines. Strange to relate, however, this area has the lowest average trichuris infestation of any of the areas, which fact again suggests differences in the etiology of these parasites. Perhaps the best evidence that sanitation in Panama has not influenced in any general way at least the intensity of the ascaris and trichuris infestations comes from the fact, already stressed, that a number of the families which have the heaviest infestations of both these parasites live in houses which have latrines in general use, and that about the same proportions of lightly infested families are found in the unsanitated groups as in the sanitated. We do not mean to say, of course, that there are no households where the introduction of latrines have not checked the dissemination of these parasites. This might certainly occur where there were no children or where the adults carefully controlled the defecation habits of the children. We are forced to the general conclusion, however, that in our Panama series as a whole the introduction of latrines, which has been shown to be a factor in limiting the spread of hookworm, has not influenced in any appreciable way the factors which are decisive in the dissemination of ascaris and trichuris.

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ABSTRACT SUMMARY.

I. *The situation in Panama with relation to the hookworm problem. By W. W. Cort and Louis Schapiro.*

This section gives first a brief description of the geography and the people of Panama. There is also included an account of the hookworm campaign from 1914 to 1926 taken from the reports sent in by the Field Directors to the International Health Board of the Rockefeller Foundation. In the early years the campaign in Panama was conducted by the dispensary method and little progress was made in latrine construction. It was only beginning with 1919 and 1920 that it was possible to stress the sanitary phases of the work. In the later years of the campaign the mass treatment method was used usually without previous examinations and later reexaminations. Wherever possible latrines were introduced before the treatment work and great stress was laid on an inspection system for conserving the sanitation. During the course of the campaign a total of 146,402 fecal examinations were made with a hookworm incidence of 86 per cent. These examinations include practically every accessible populated region of the country. The section closes with a detailed description of the areas from the Penonome and Santiago districts where the intensive studies were made in the summer of 1926. W. W. Cort.

II. *Laboratory methods in the Panama studies. By N. R. Stoll.*

The routine procedures of the dilution egg counting and Willis flotation technics as applied to hookworm, ascaris and trichuris ova are described, and certain results on the time required to carry them through are noted. In addition the comparative lack of efficacy of the Willis technic in diagnosing ascaris infections is shown at the same time when hookworm and trichuris infections are diagnosed with a relatively high efficiency. N. R. Stoll.

III. *Stool size and its relation to eggs in the feces. By N. R. Stoll.*

In the use of egg counts to measure worm burdens, the fundamental measurement is the number of eggs passed per day by the infected host. The usual type of data gathered for analysis, however, are egg counts per gram or c.c. of the original stool. In such data inhere

three variables not involved in the total egg outputs per day. These are, respectively, consistency of the stool portion examined, the total amount of fecal output per day and the different sized stools due to age, the latter two points being considered in relation to consistency of stool. From the analysis of 90 stools collected from one of the villages in Panama, it was possible to verify the usual finding that formed, soft-formed and mushy feces were in an output ratio per day as 1 : 1 1/2 : 2. It was determined also that the average output by adults of formed feces per day approximated 100 grams, being thus similar to the China results, but contrasting with about 150 grams in Porto Rico. Moreover, twenty four hour fecal outputs, basis formed stools, when analyzed according to age of donor, showed that at ages 1–2 the daily amount was about one quarter, and at ages 3–4 about one half of the adult average. This means that the egg counts for young children must be corrected for stool size when compared with those of adults. The effect of such facts on the interpretation of egg count data is emphasized, as well as the desirability of gathering more information on normal stool sizes in populations elsewhere in the world. N. R. Stoll.

IV. *The correction of hookworm rates for age and sex. By W. C. Sweet.*

The comparison of incidence or intensity rates for hookworm (and other parasites) as between different localities is usually made on the basis of the exact figures secured from the group sampled. Rarely do such groups represent fair samples of the whole age distribution, and they are frequently overloaded from the standpoint of one sex or the other. The comparisons between different areas using such data are, therefore, necessarily faulty in that they have no common "base line." A correction for this difficulty is available in the use of incidence and intensity rates interpreted in terms of a standard population. For such a standard the population of Porto Rico, 1910, has been chosen, in that it is tropical in character, as are most populations whose hookworm incidence or intensity are determined. Not only is the use of such a standard population suggested for the correction of hookworm rates generally, but it is also strongly urged that any age combinations made be on such a basis that they can be amalgamated into the usual census groupings, 0–4, 5–9, 10–14, 15–19, 20–29, 30–39, etc. The way in which such standardization facilitates comparisons between statistics from widely separated areas is illustrated. N. R. Stoll.

V. *An analysis of hookworm infestation in areas in Panama uninfluenced by control measures. By W. W. Cort, W. A. Riley, W. C. Sweet, Louis Schapiro and N. R. Stoll.*

This section includes the studies on soil pollution and soil infestation and the analysis of the egg counts in those of the Panama areas where there had been little if any control work. Climatic and soil factors are apparently quite favorable in the part of Panama where the studies were made since there was found a high level of hookworm infestation both in the coastal plains with sparse vegetation and a rainfall of about 60 inches a year and in the uplands where the rainfall was over 100 inches a year and where there was a much denser vegetation near the houses. The average egg counts of the coastal plains groups studied was about 10,000 eggs per c.c., while that of the upland areas was about 50 per cent. higher. This difference was attributed to the heavier rainfall and denser vegetation near the houses found in the upland and hill regions. The size of the infestations in Panama are shown to be remarkably large as compared with other regions of the world where measurements have been made by quantitative methods. The infestation in adult males is almost uniformly considerably greater than in females. This difference was tentatively explained on the basis of agricultural occupations of the males away from home and the avoidance in certain cases by the females of the dangerous places of soil pollution frequented by the males. The infestations in children in some of the upland areas are extraordinarily heavy as compared with those found elsewhere and on the whole the children show unusually high egg counts.

The chief factors which produce the extraordinarily heavy hookworm infestations in the Panama areas were apparently the long rainy season, the intense soil infestation near the houses produced by the soil pollution habits of the people and the almost universal absence of shoes in the ordinary daily occupation. No particular occupational relations were found which brought certain groups into more danger of infection than others. The soil pollution habits of the people and the types of situations where the depositing of stools produced soil infestation are discussed in considerable detail. The conclusion is drawn that the seeking day after day of protected places for defecation often at considerable distances from the houses might in itself account for much infection. Further the spreading of stools widely in grassy places or the scattering of them in shaded areas near the houses would tend during the long rainy season to develop extensive soil infestation dangerous to both children and adults in the ordinary

activities of the daily routine. Hookworm in Panama, therefore, as in many places recently studied appears to be pretty largely a question of family sanitation, with the unusually high level of infestation apparently due largely to the long rainy season. W. W. Cort.

VI. *A study of the effect of treatment and sanitation on the level of hookworm infestation in certain areas in Panama. By W. C. Sweet, W. W. Cort, Louis Schapiro, N. R. Stoll and W. A. Riley.*

This section includes an analysis of the egg counts from areas in Panama where hookworm control work had been carried on. The control in the areas studied in most cases was only partial and not of the efficiency of that of the last few years. A comparison of these partially controlled communities with those where little or no work had been done gives information on the effectiveness of the campaign in reducing the level of infestation.

The comparison of treated and untreated individuals living in unsanitated communities shows a rapid return of the treated individuals to the level of infestation of the untreated group. In the upland type of community with its heavier infestation practically no evidence of the effect of treatment remained after three years except in isolated families. In one of the unsanitated coastal plains areas, on the other hand, the treated group after four years showed an infestation only about two thirds that of the untreated. In sanitated areas, the treated individuals living in houses with latrines showed a considerably lower infestation even after six or seven years than the untreated living under like conditions. It was found that the effect of the treatments could be demonstrated after a longer period and were greater in those communities where the latrines were built at the same time that the treatments were given as compared with communities where the sanitation came at a considerable interval after treatment.

As compared with rural areas where comparable control work had been carried out the poorer sections of the towns had a surprisingly high hookworm infestation, indicating that under conditions of soil pollution the crowded situation of the towns is particularly favorable in Panama for the building up of a high level of infestation.

Comparisons of the people alike in regard to treatments living in houses with latrines in these partially sanitated areas with those without latrines showed in every case a strikingly lower average infestation in the first group. In one such community the individuals living under sanitary conditions had an average egg count only 30 per cent. of that of the unsanitated.

When the communities where partial control work had been done are considered as a whole it is found that there had been definite reductions in the level of hookworm infestation, in one case the average of two such communities being about 60 per cent. of that of comparable places where there had been no control work. The fact is, however, that the effect of the treatment and building of latrines in reducing the level of hookworm infestation is rather small and these communities have a surprisingly high egg count and there are still numbers of clinical cases. This study suggests that much remains to be done in Panama before hookworm can be brought under control. The more recent developments of the campaign with its presanitation and emphasis on the sanitary inspection seems a very sound procedure. It is suggested that the treatment campaigns should be repeated in these partially controlled areas after sanitation has been brought up to as high a level as possible. W. W. Cort.

VII. *Hemoglobin levels in Panama as a measure of the intensity of hookworm infestations. By W. W. Cort, Louis Schapiro, W. C. Sweet, N. R. Stoll and W. A. Riley.*

Hemoglobin determinations made by the Talquist scale on large numbers of individuals during the routine work of the Department of Uncinariasis show for most places in Panama a general anemia which is attributed to the heavy widespread hookworm infestations. This anemia is less in the cities than in the rural districts. A distinctly higher hemoglobin index was found in a considerable number of cases examined one to two months after treatment.

Hemoglobin determinations made by the Talquist scale for a considerable proportion of the series of individuals studied in the summer of 1926 from Panama are analyzed in comparison with their egg counts. In the nine areas studied from Cocle province including the town of Penonome, the coastal plains villages and the hill communities of Marica Arriba and Sardina the people showed a remarkable resistance to the anemia producing effect of their hookworm burden since even in groups with average egg counts of 10,000 eggs per c.c. and over the hemoglobin averages were 60 per cent. or higher. Very little negative correlation either in individual cases or in intensity groups was present between the size of the egg count and the hemoglobin per cent. This resistance was present in unsanitated and untreated groups as well as those in which control work had been done. It did not seem to be due to unusually good nutrition since some of the groups of people showing it were very poor and apparently undernourished. The

suggestion is made that this resistance to the production of anemia is due to the small amount of white blood in these groups, although it may be due to some unknown factor or factors peculiar to this district.

In contrast the comparison of the hemoglobin percentages and egg counts of individuals from two villages in the upland regions of Veraguas province shows a very considerable degree of anemia produced by infestations no heavier than some from the other region. Here there is negative correlation between the size of the egg counts and the hemoglobin percentages. These people differ from the other groups in having a much greater proportion of white blood. These comparisons suggest the need of further studies on the factors influencing the degree of anemia produced by hookworm infestations, since they show that people from two districts of the same country may be influenced to an entirely different degree by hookworm infestations of comparable intensity. W. W. CORT.

VIII. *Quantitative studies on the distribution of* Ascaris lumbricoides *and* Trichuris trichiura *in Panama. By W. W. Cort, N. R. Stoll, W. A. Riley and W. C. Sweet.*

From the evidence available from the analysis of our Panama egg counts we are able to bring forward the following facts on the distribution of ascaris and trichuris and advance the following views on the factors influencing their dissemination:

1. Children have much heavier average infestations than adults.
2. Young adult females are more heavily infested than males.
3. Differences in rainfall as far as found in the areas studied do not produce significant differences.
4. The poorer sections of towns offer conditions particularly favorable for their spread.
5. Treatment and sanitation as developed in the control work against hookworm do not appear to have limited their dissemination.
6. Certain differences of intensity of ascaris and trichuris infestation in the same age groups, in certain families and in certain population groups suggest differences in the etiology of these two parasites which we have no information to explain.
7. Finally, while hookworm in Panama appears to be chiefly spread from pollution by adults at some distance from the houses, ascaris and trichuris appear to depend chiefly for their dissemination on stools deposited by young children close to the houses, so that the immediate environs of the houses and the floors themselves become impregnated with the eggs. W. W. CORT.

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